NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1057

GENERAL TANK TESTS OF A $\frac{1}{10}$-SIZE MODEL OF THE HULL OF THE BOEING XPBB-1 FLYING BOAT - LANGLEY TANK MODEL 175

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SUMMARY

General tank tests of a $\frac{1}{10}$-size model of the hull of the Boeing XPBB-1 flying boat were made in Langley tank no. 1. Tests were made of the forebody alone, the forebody with afterbody, and the forebody with afterbody and tail extension, which represented the complete hull.

In addition to the usual measurements of resistance and trimming moment, measurements were made of the length of the planing bottom which was wetted by the water. The draft of the forebody alone was measured by a method which eliminated errors caused by up-and-down surges of the water in the tank.

The application of the data to the determination of stability derivatives, frictional resistance, and the computation of the forces on the constituent parts of the hull is discussed briefly.

INTRODUCTION

For some time a need has existed for adequate data from which the stability derivatives of a flying-boat hull may be computed. Such analytical work on the stability of hulls has heretofore been based on the results of tests of planing surfaces by Shoemaker (reference 1) and Sottorf (reference 2) and has usually been restricted to low-angle porpoising. The models used by Shoemaker did not have chine flare and the tests did not extend to low speeds (speeds at and below the region of the hump) at which buoyancy contributes a large part of the total lift and at which a hull operates primarily as a displacement craft. A better evaluation of the stability derivatives of hulls could be obtained if the data from tests of planing surfaces were supplemented by data obtained at speeds above and below those given in references 1 and 2 and if the tests giving such data were made with planing surfaces having chine flare representative of that used on modern flying-boat hulls. Resistance tests of hull models and planing surfaces, in general, have not provided data sufficient either in accuracy or amount to allow a satisfactory determination of the stability derivatives involved in porpoising, especially those involved in high-angle porpoising - a type of instability that involves both the forebody and afterbody. One source of inaccuracy in such tank data lies in the determination of the draft of the model by measuring the vertical position of the model with respect to the towing carriage. This inaccuracy could be eliminated if the draft were determined by a direct measurement between the model and the water surface.

The effect of Reynolds number on the frictional resistance is customarily neglected in converting model results to full size because the frictional resistance is only a small part of the total resistance and because the wetted area of the bottom of the hull is not determined in the usual tank tests. A knowledge of this frictional resistance, however, should be of use in an analytical investigation. It is often of interest to know the forces due to the constituent parts of the hull. A report of some work on this subject is given in reference 3.

In order to make available some data to supply the aforementioned needs, especially with regard to the Boeing XPBB-1 flying boat, general resistance tests of a $\frac{1}{10}$-size model of the hull of the XPBB-1 flying boat were made. Tests were made of the forebody alone; the forebody with afterbody; and the forebody with afterbody and tail extension, which represented the complete hull. In addition to the usual measurements of resistance and trimming moment, measurements were made of the length of the planing bottom which was wetted by the water. Some determinations of the draft of the forebody alone were made by measurements of the height of the model with respect to the water.

SYMBOLS

C_Δ load coefficient $\left(\frac{\Delta}{wb^3}\right)$

C_R resistance coefficient $\left(\frac{R}{wb^3}\right)$

C_p center-of-pressure coefficient (c.p./b)

C_d draft coefficient (d/b)

C_V speed coefficient $\left(\frac{V}{\sqrt{gb}}\right)$

Δ load on water, pounds

w weight density of water, pounds per cubic foot (63.4 for these tests)

b beam of hull, feet

R resistance, pounds

c.p. center of pressure, feet (distance from step to intersection of resultant force vector and keel or line of keel extended)

d draft at step, feet

V speed, feet per second

g acceleration due to gravity, 32.2 feet per second per second

τ trim, degrees

MODEL

The lines of the model, which were furnished by the Boeing Aircraft Company, are given in figure 1, and a sketch showing the parts of the model is given as figure 2. The forebody alone was designated Langley tank model 175F; the forebody with afterbody, model 175FA; and the forebody with afterbody and tail extension, model 175FAT.

The forebody was built of laminated mahogany. The afterbody was of built-up construction with a transparent bottom to facilitate measurements of the wetted length at the keel. When attached to the forebody, the afterbody was strongly braced so that deflections of it relative to the forebody were negligible. The sides of the afterbody of model 175FA were extended above the parting line shown in figure 2 to keep water from entering the afterbody. The tail extension was that used in a $\frac{1}{10}$-size dynamic model of the XPBB-1 flying boat.

The bottom of the forebody was prismatic for a distance of 1.5 beam lengths forward of the step. The keel of the forebody was straight for a distance of 2.4 beam lengths forward of the step. The angle of dead rise of the forebody, including chine flare, was 17.9° and that of the afterbody was 20°. Excluding chine flare, the angle of dead rise of the forebody was 20°.

TESTING APPARATUS AND PROCEDURE

A description of Langley tank no. 1, the towing equipment, and the method of testing is given in reference 4. Fixed-trim and free-to-trim tests were made by the general method. The results of the free-to-trim tests on models 175FA and 175FAT were used to assist in the fairing of the results of the fixed-trim tests and are not given herein. Tests of model 175FAT were made only for the conditions when the tail extension was in the roach of the afterbody.

In addition to the usual measurements of resistance and trimming moment, measurements were made by visual observation of the lengths of the planing bottoms wetted by the water. The wetted lengths of the forebody and afterbody were measured with respect to the step and stern post, respectively, for models 175F and 175FA. The wetted length of the chine was measured to the intersection of the chine and the free-water surface, even though spray crosses the chine forward of this point, as shown in figure 18 of reference 5. Under some conditions at low speeds, the flow of water on the afterbody was so disturbed that accurate measurements of the wetted lengths could not be made. (See reference 6.)

The centers of pressure were computed from the forces and moments measured about a point 16.88 inches above the forebody keel and 3.87 inches forward of the step.

The measurements of draft of model 175F were made by a new procedure. A movable graduated prod was attached to the bow and adjusted during the run until the end of the prod touched the surface of the water ahead of the model. The draft could then be computed from the trim and the reading of the prod. The method ordinarily used to measure draft at the Langley tanks is described in reference 1 and consists essentially in measuring the vertical position of the model with respect to the towing carriage. The flow of air around the towing carriage, however, creates a pressure field that moves along the tank with the carriage and produces a wave motion of the water and of the model with respect to the carriage. The change of height of water is a function of the carriage speed on the test run and preceding runs, the time interval between runs, and other factors; this change may, on occasion, be as large as the draft of the model. Any inaccuracy introduced by the wave motion of the water in the tank is eliminated by use of the prod.

RESULTS AND DISCUSSION

Test Results

For convenience in reading, the faired curves of the results are given without test points. Figure 3 presents data of tests of model 175F at 8° trim and shows the scatter of test points. This scatter in figure 3 may be considered as typical of that of the other figures.

(The results of the tests are given in figures 4 to 10 in the form of curves of resistance coefficient C_R, center-of-pressure coefficient C_p, wetted lengths, and draft coefficient C_d plotted against speed coefficient C_V, with trim τ and load coefficient C_Δ as parameters.)

A comparison of figures 4 and 5 shows that, at speeds up to hump speed, the resistance of the forebody alone was greater than the combined resistance of the forebody and afterbody at the same load and trim. This difference indicates that, at these speeds, the load-resistance ratio of the afterbody was greater than the load-resistance ratio of the forebody. This result corroborates the results given in reference 3. At high speeds, however, the resistance of the forebody and afterbody was greater than that of the forebody alone because of afterbody wetting, except at high trims when the load was entirely supported by the afterbody (figs. 8 and 9). Figures 5 and 6 indicate that the tail extension had little effect on the resistance at a given load and trim.

At low speeds, the presence of the afterbody and tail extension moved the center of pressure aft. At high speeds the tail extension was not involved and the afterbody had a negligible effect on the center of pressure except at the high trims when all of the load was supported by the afterbody.

The drafts computed from the keel wetted-length data of figure 7 were compared with the drafts given in figure 10 at speed coefficients of 4 and above. At trims of 4° and 8°, the average differences between the two values of draft were within the experimental error. At 10° trim the computed drafts were, on the average, 0.02 beam lengths greater than the measured drafts.

Some Applications of Data

The data presented is suitable for the computation of stability derivatives according to the methods given in references 7 to 10.

The wetted-length data permit a Reynolds number to be computed for any size of hull and speed. The variation of the coefficient of frictional resistance with Reynolds number is well known. (See chapter XII of reference 11.)

The computation of the forces due to the constituent parts of the hull may be made by subtracting the forces on the forebody from those on the forebody and afterbody to obtain the forces due to the afterbody. When the load on the forebody is known, the other forces may be obtained. At any arbitrary trim, speed, and load, the wetted length of the forebody keel is known from figure 8, and the load on the forebody can be found from figure 7 if the speed, trim and wetted length of the keel are known. The wetted length of the forebody keel was more sharply defined than that of the forebody chine and, hence, is more reliable in computing the load on the forebody.

CONCLUDING REMARK

General tank tests of the model of the hull of the Boeing XPBB-1 flying boat were made to determine, in addition to the usual measurements of resistance and trimming moment, measurements of the length of the planing bottom which was wetted by the water. The measurements of draft, which were unaffected by up-and-down surges of water in the tank, made the data particularly suitable for the computation of stability derivatives.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., May 24, 1946

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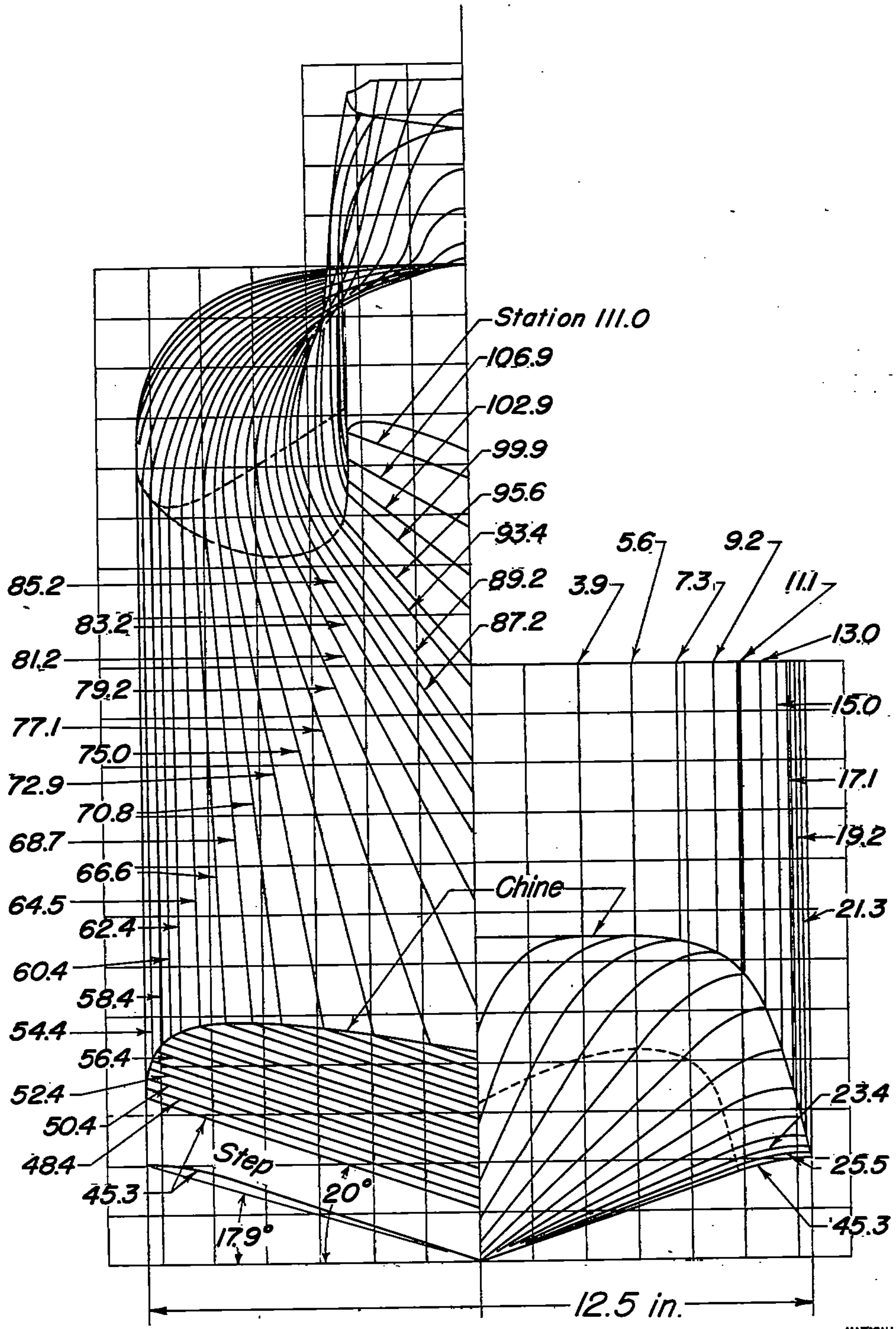

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Figure 1. - Lines of hull of Boeing XPBB-1, Langley tank model 175 FAT.

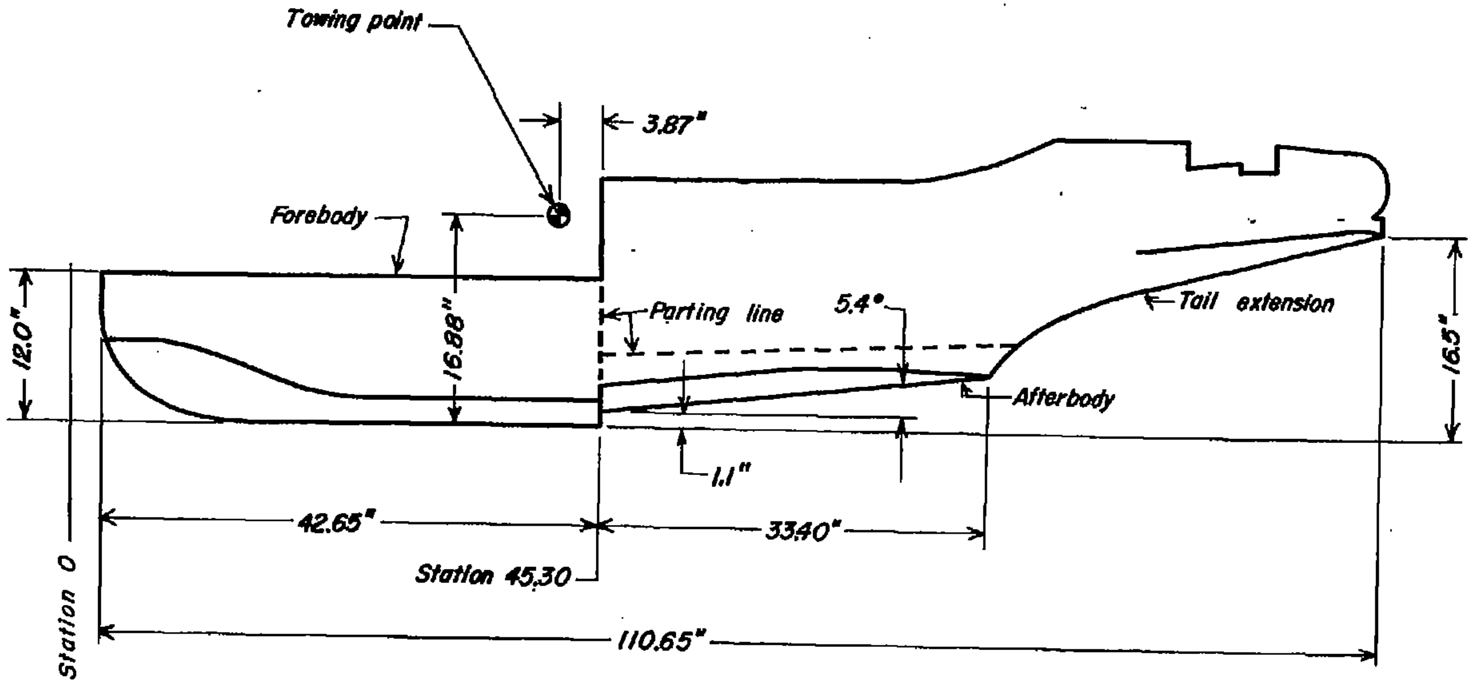

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Figure 2.— Sketch showing parts of model of hull of XPBB-1.

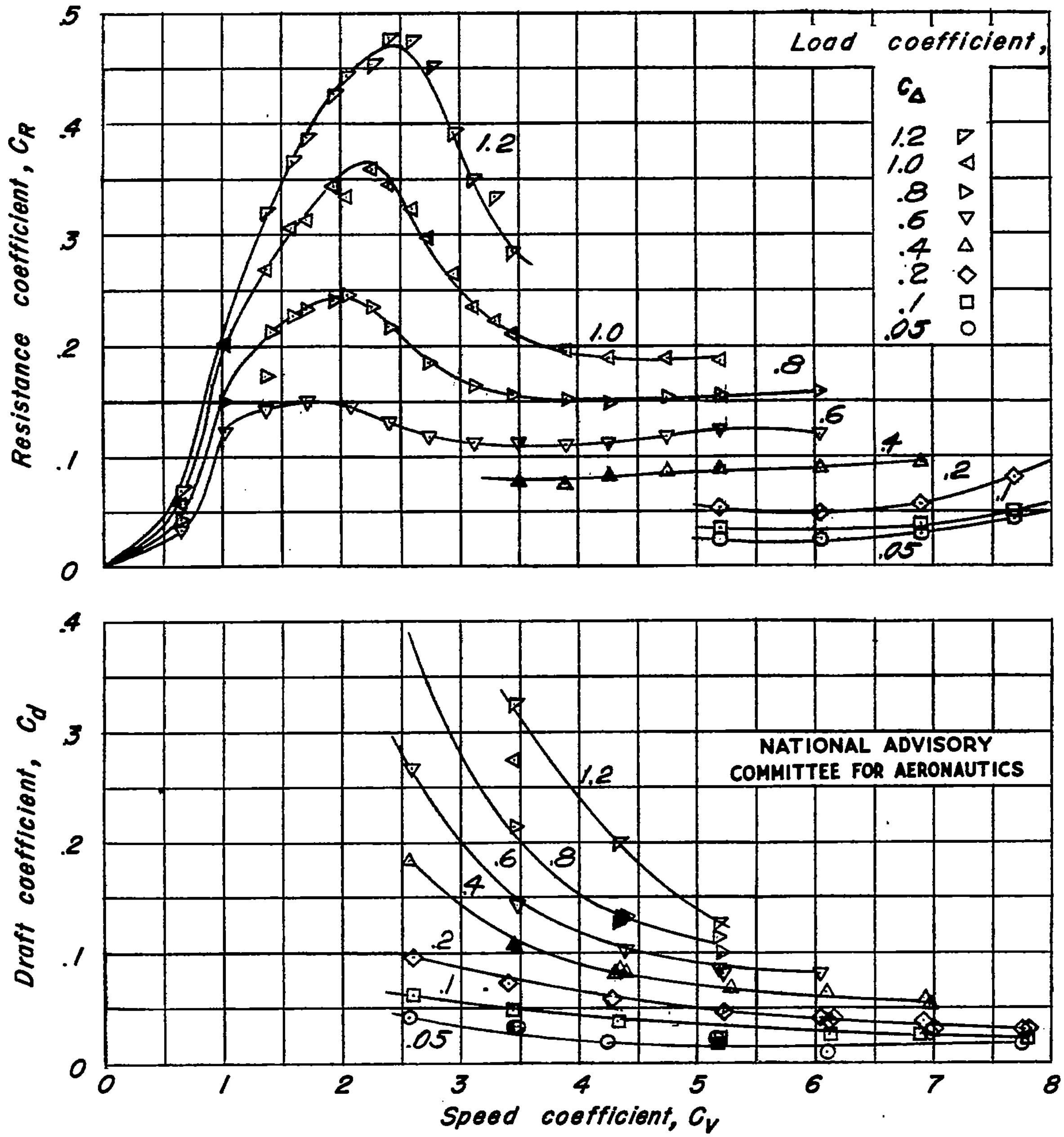


Figure 3.- Sample plot showing scatter of test points. Model 175 F; trim, 8°.

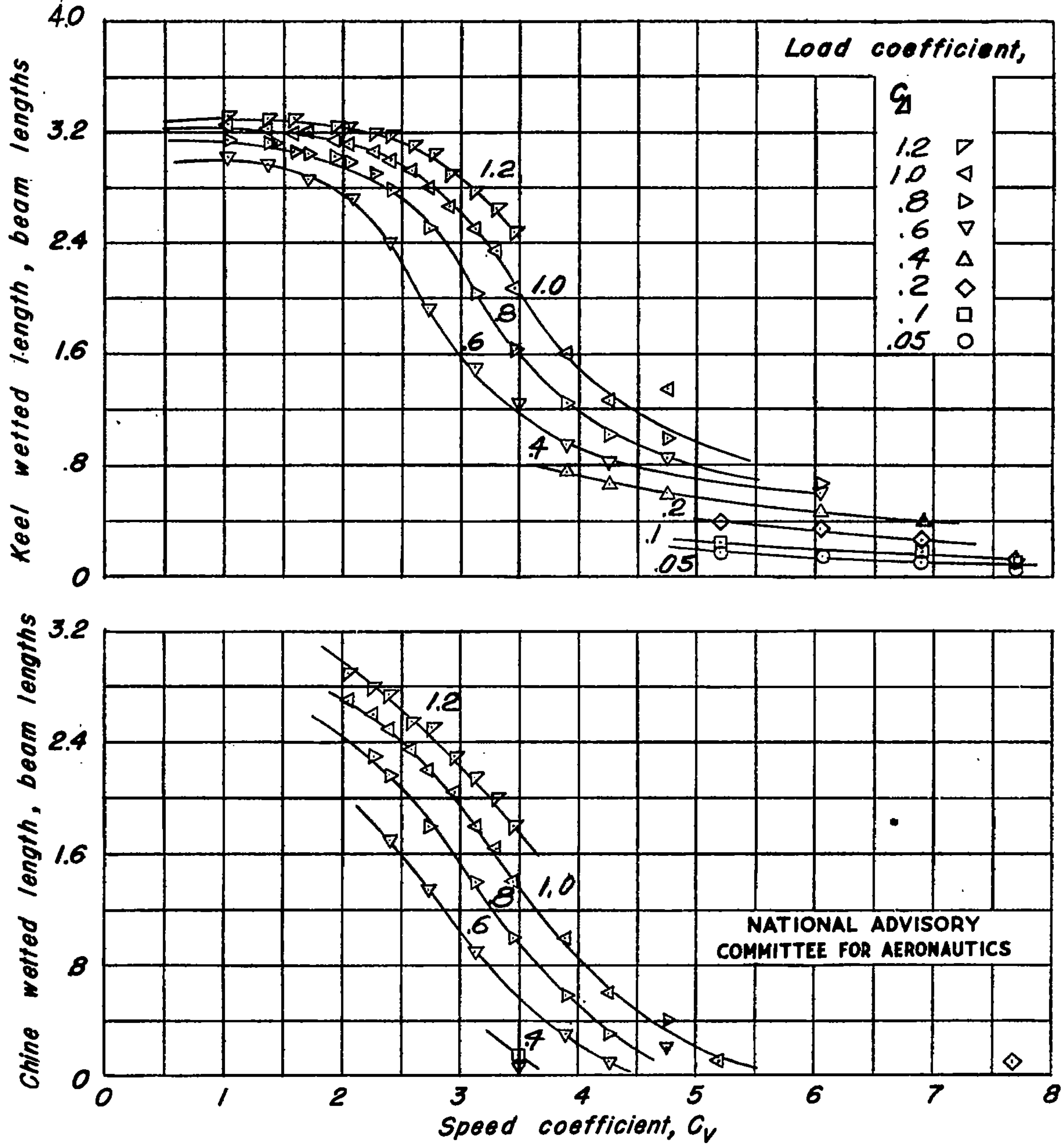
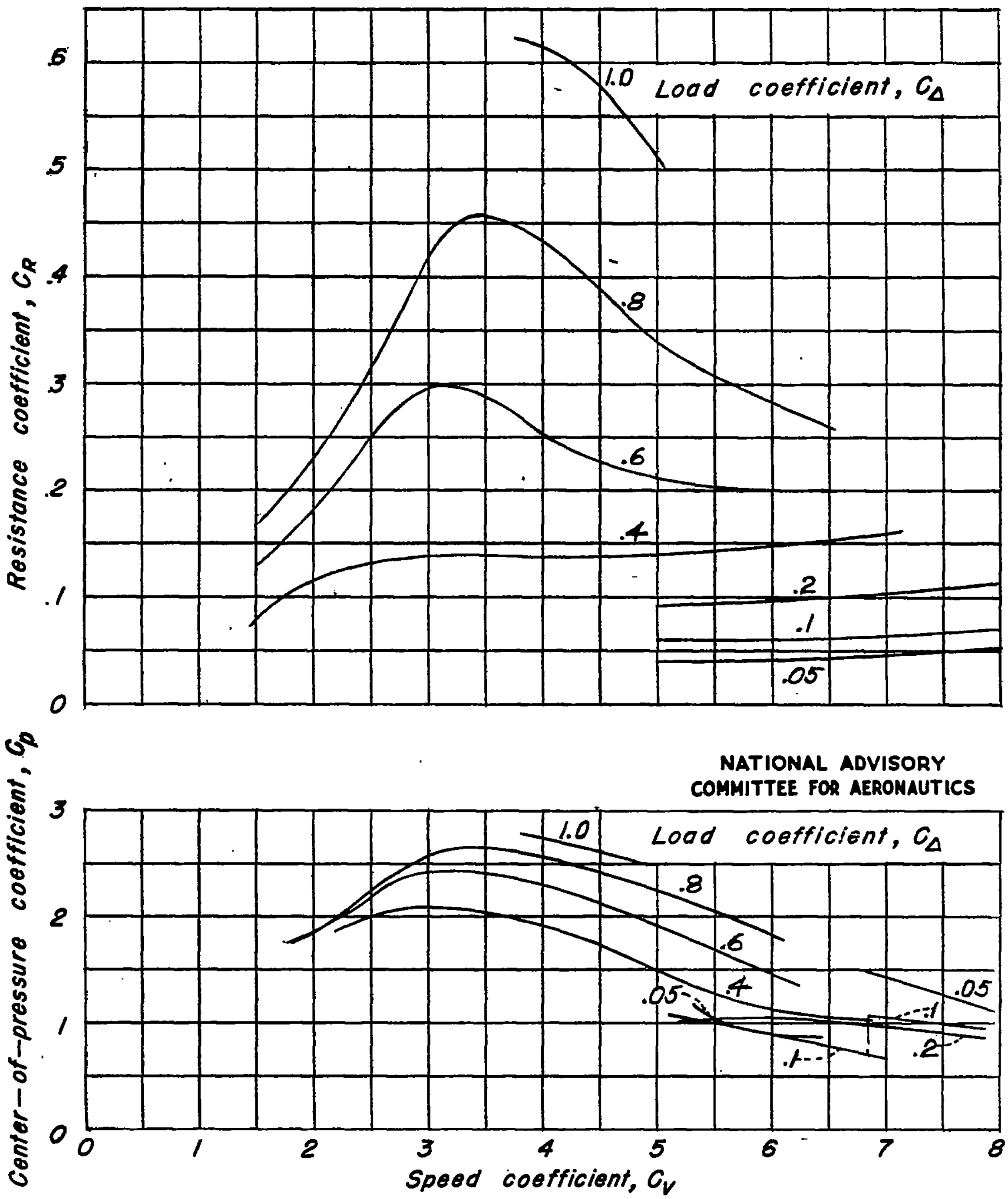
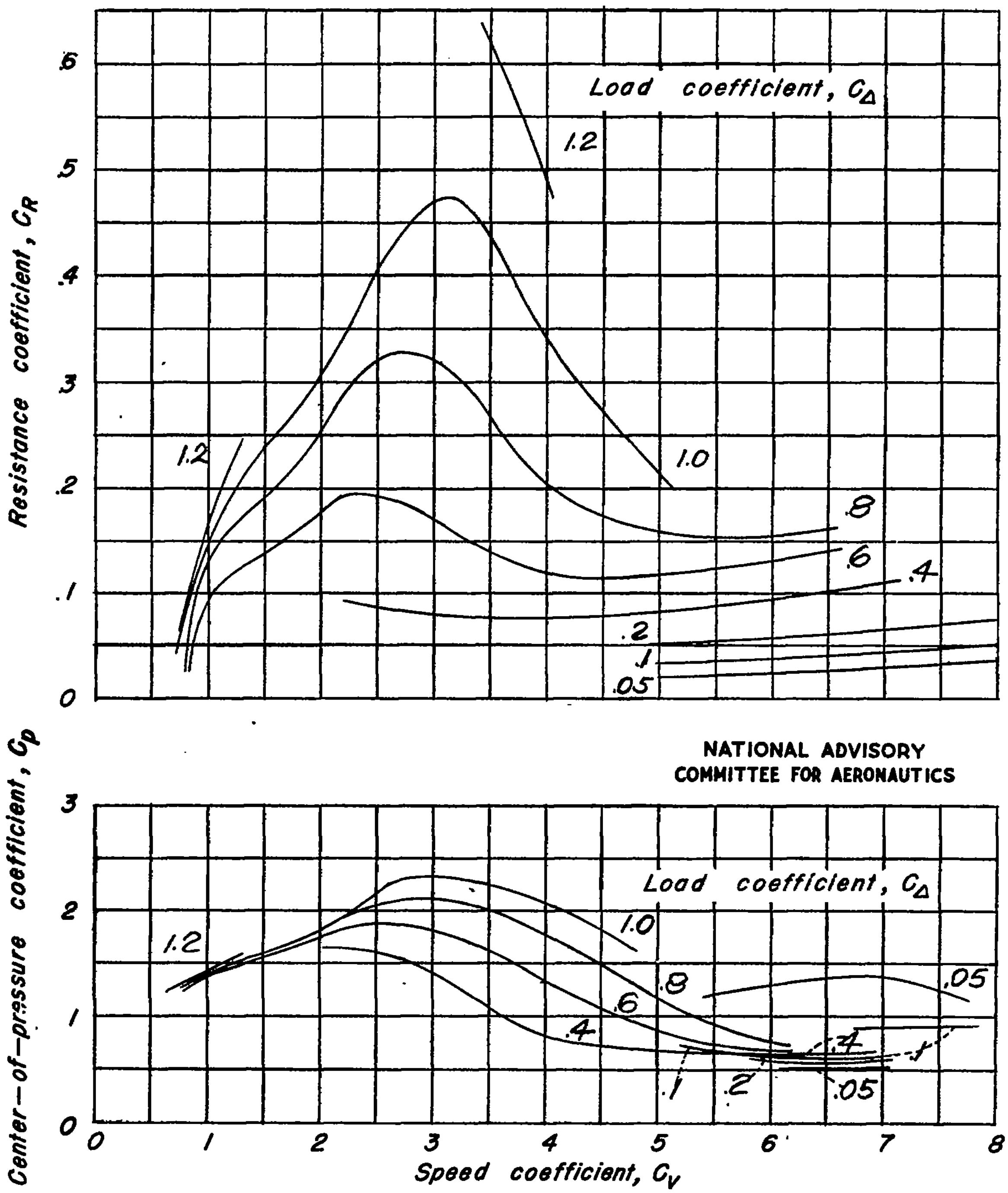


Figure 3.– Concluded.



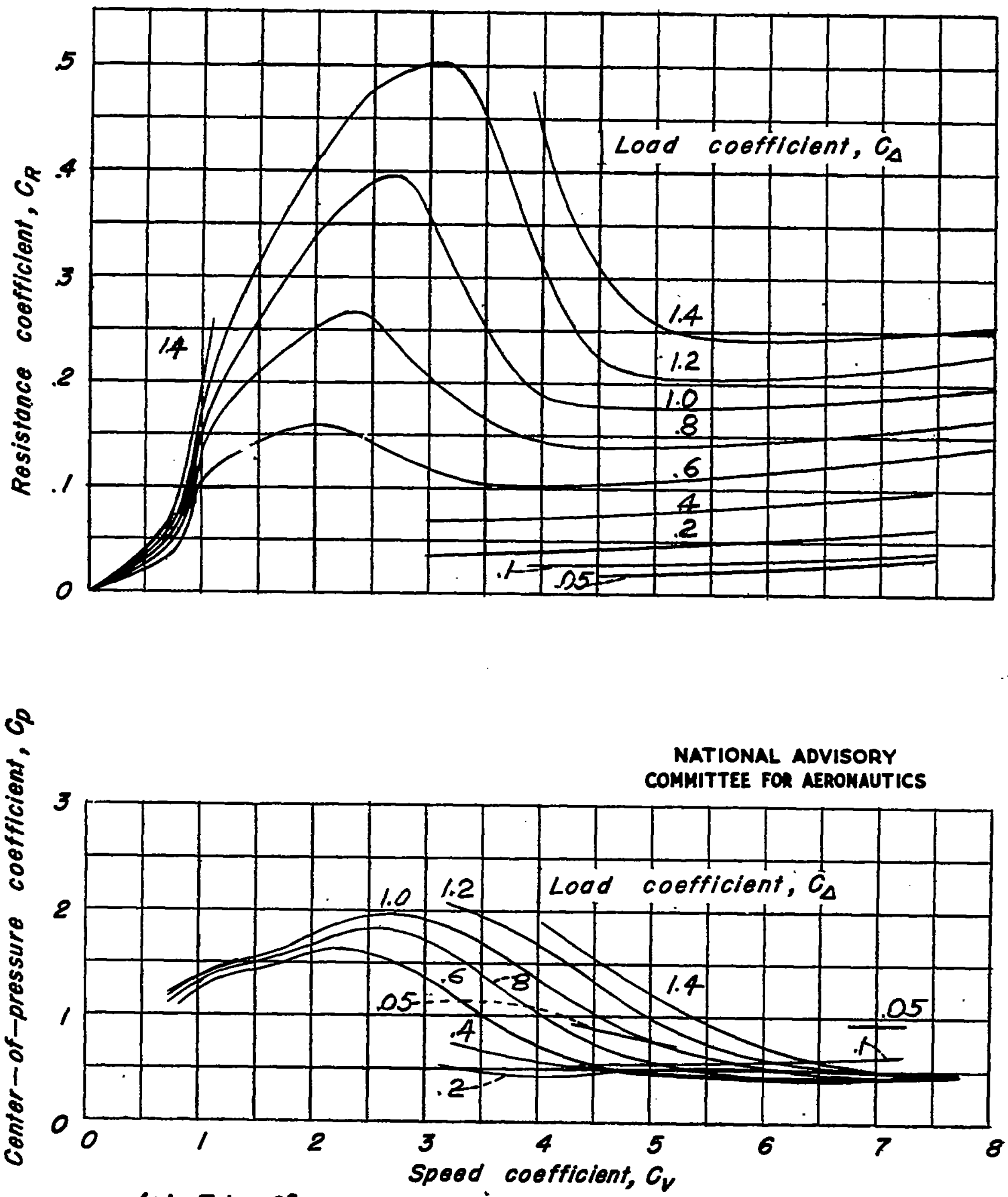
(a) Trim, 2°.

Figure 4.– Resistance and center of pressure. Model 175F.

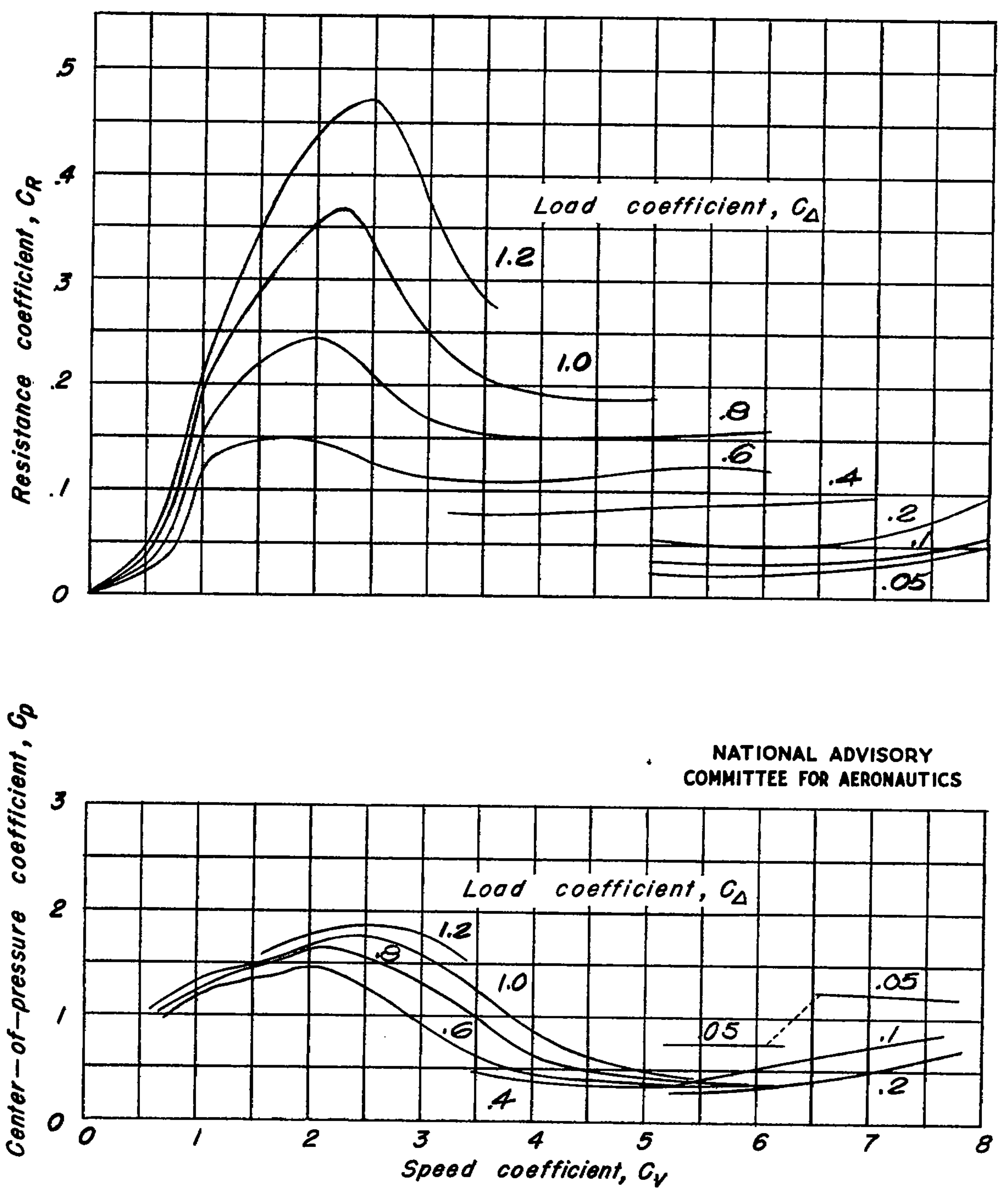


(b) Trim, 4°.

Figure 4.– Continued.

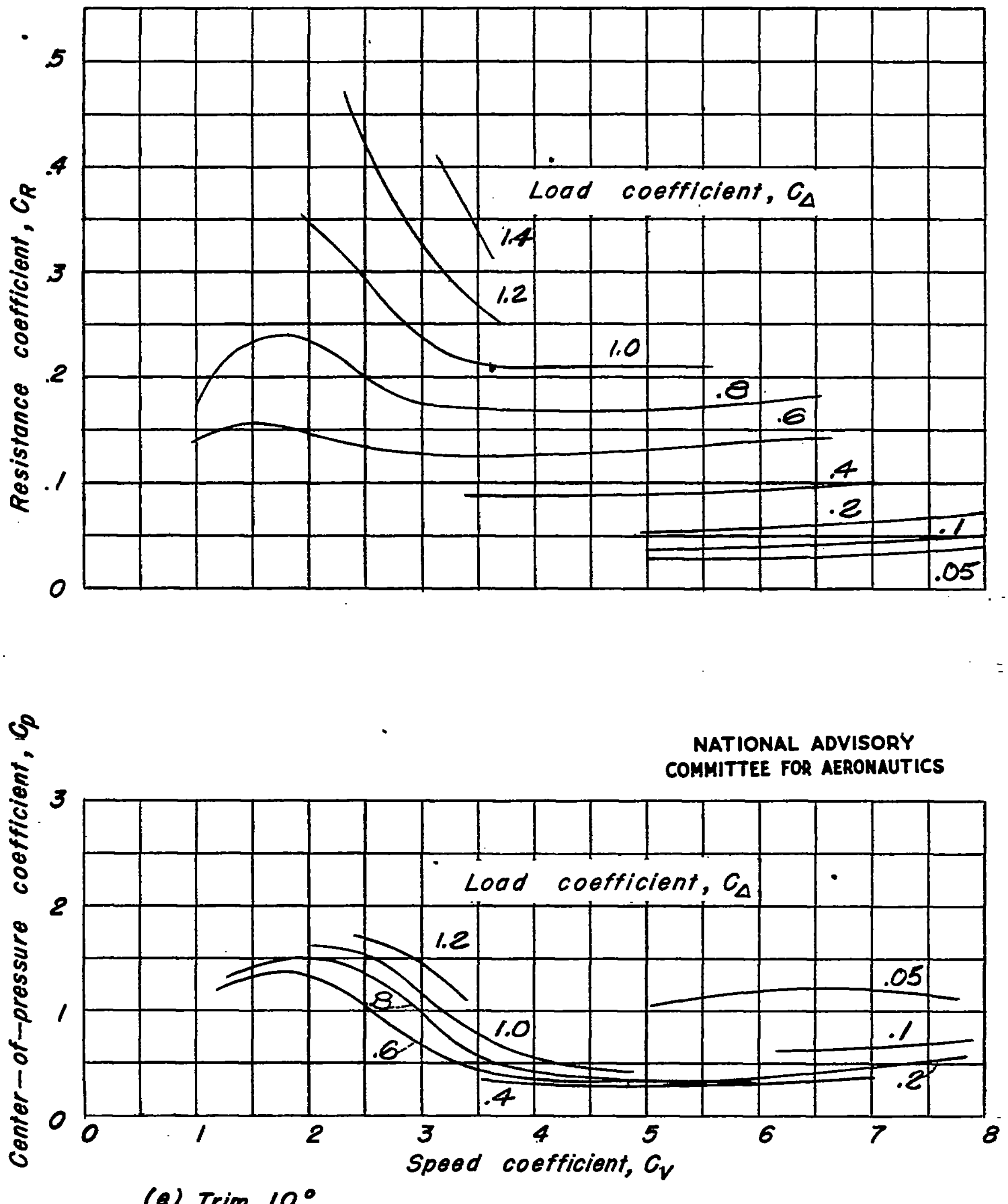


(c) Trim, 6°.
Figure 4 .- Continued.



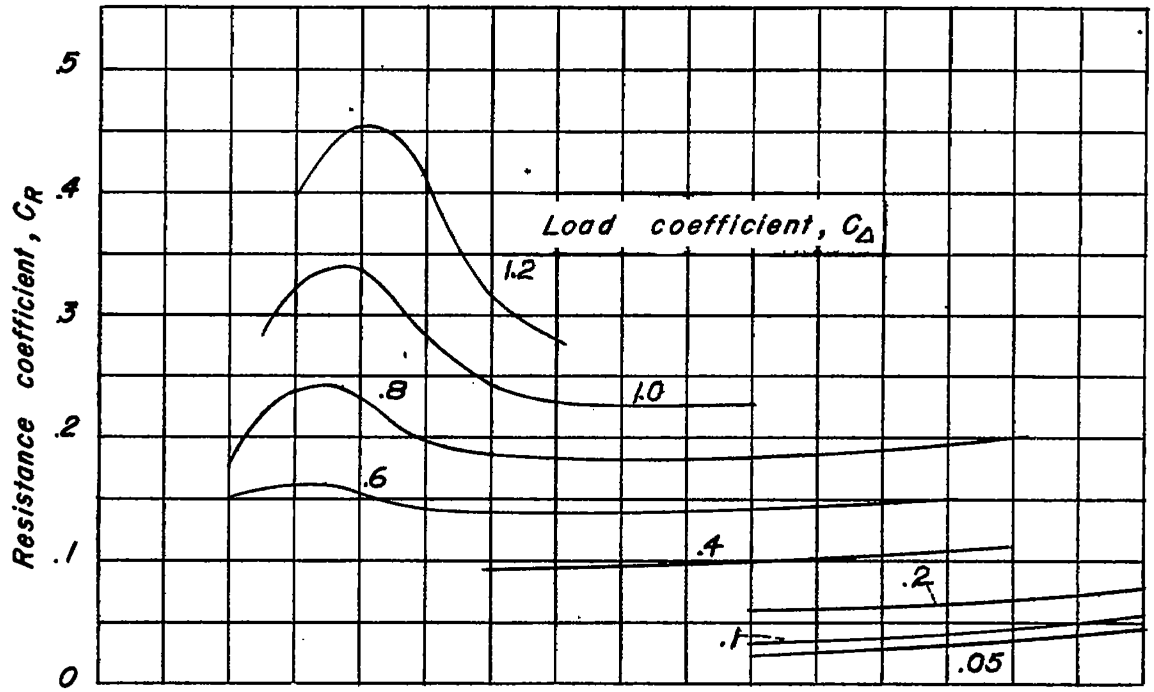
(d) Trim, 8°.

Figure 4.- Continued.



(e) Trim, 10°.

Figure 4.- Continued.



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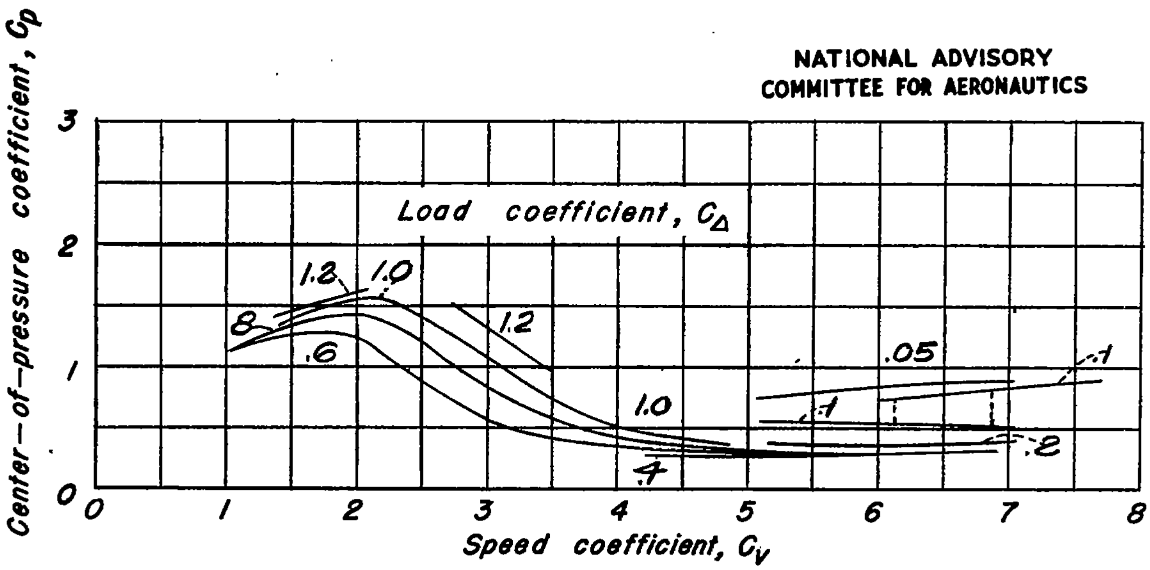
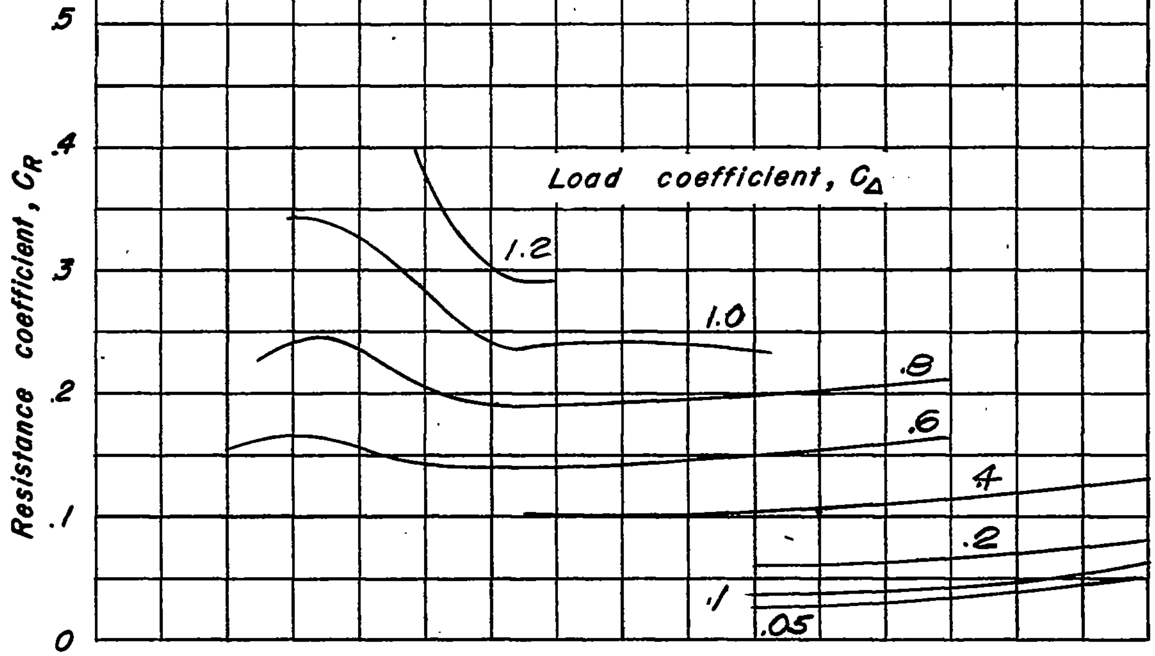


(f) Trim, 11°.
Figure 4 .- Continued.



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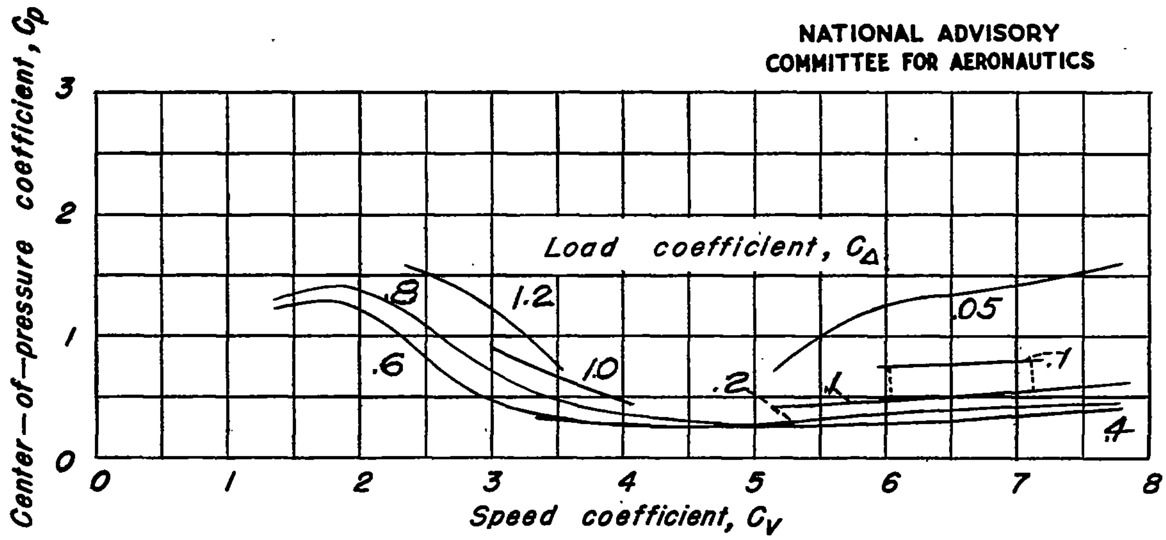
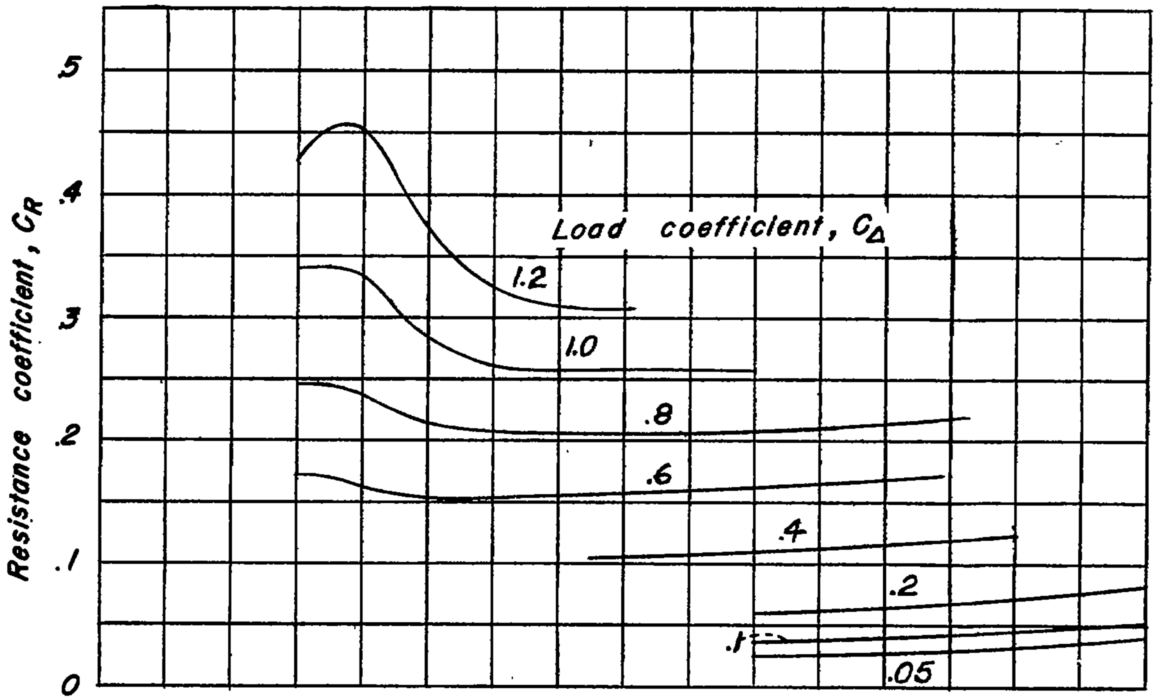


(g) Trim, 12°.

Figure 4.– Continued.



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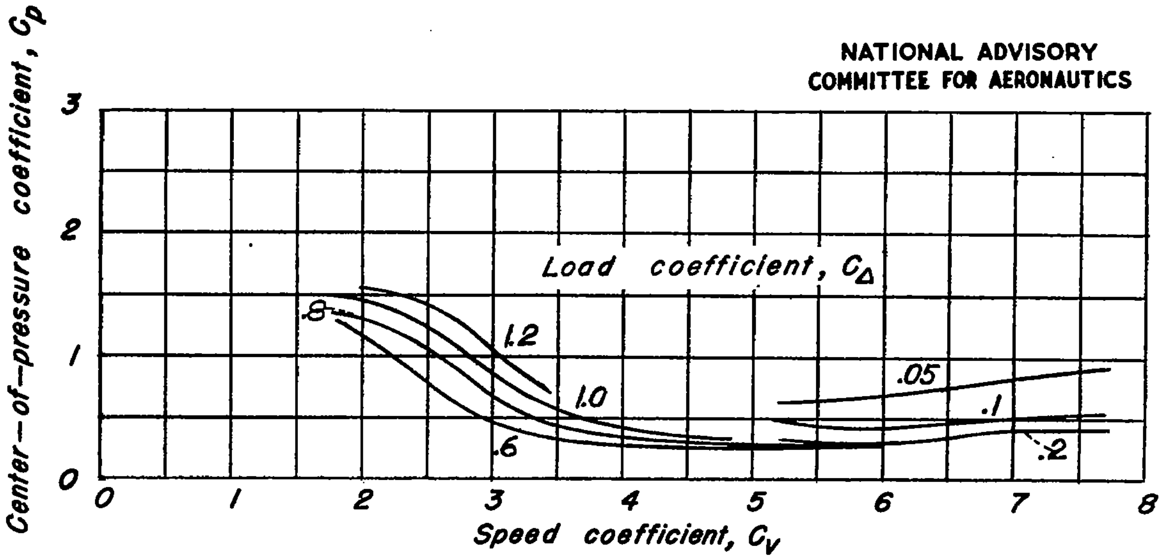
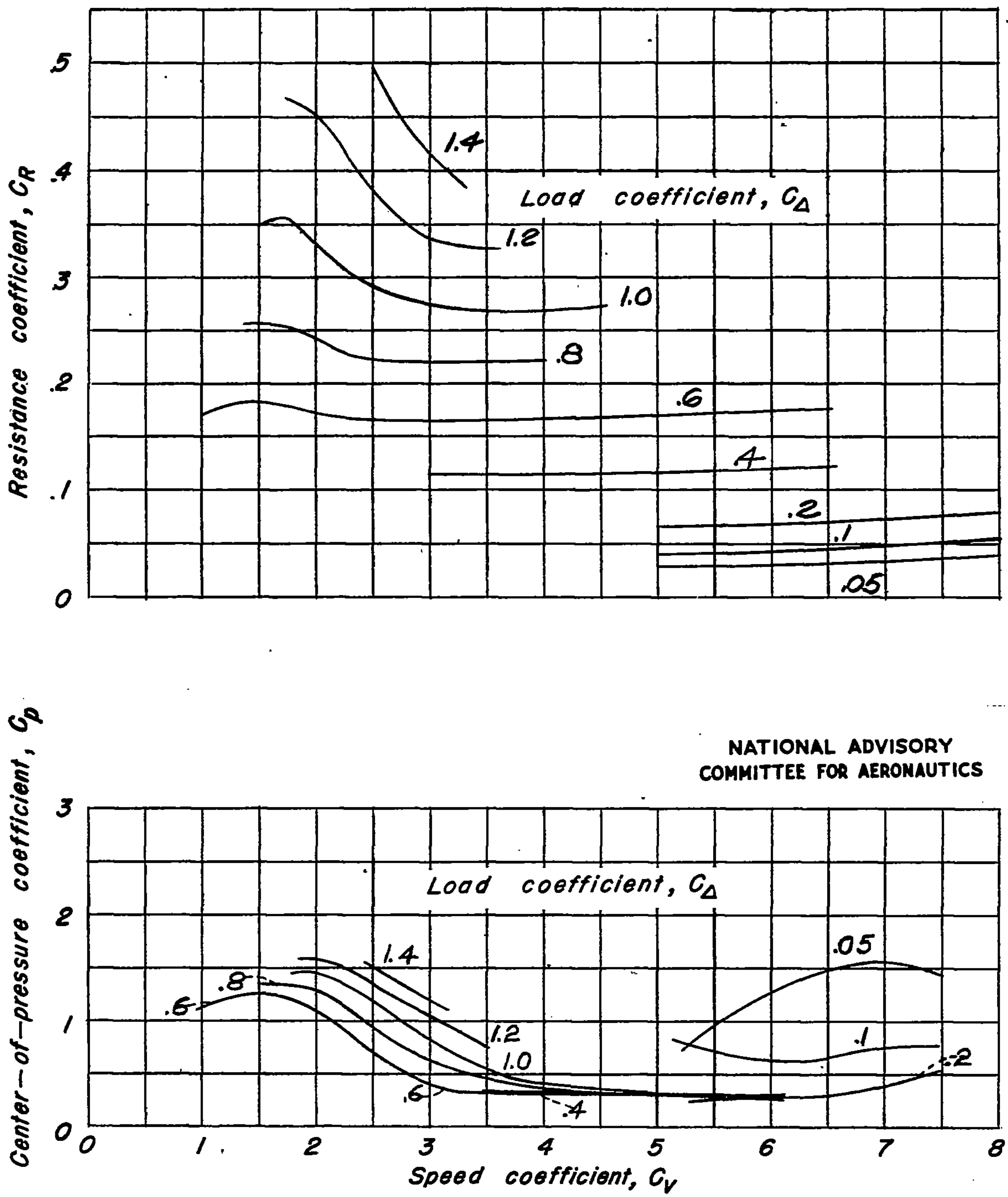


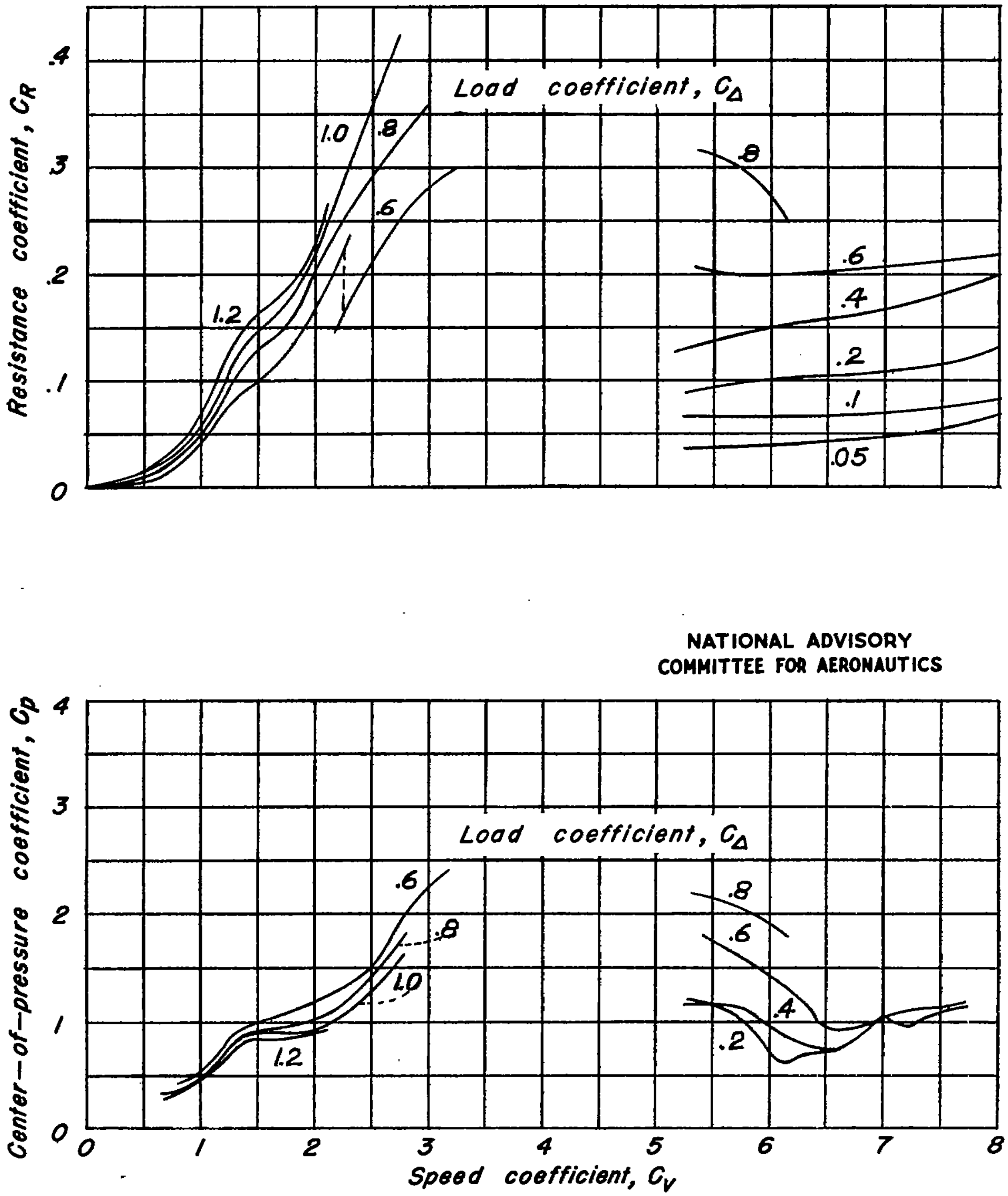
(h) Trim, 13°.

Figure 4 .- Continued.



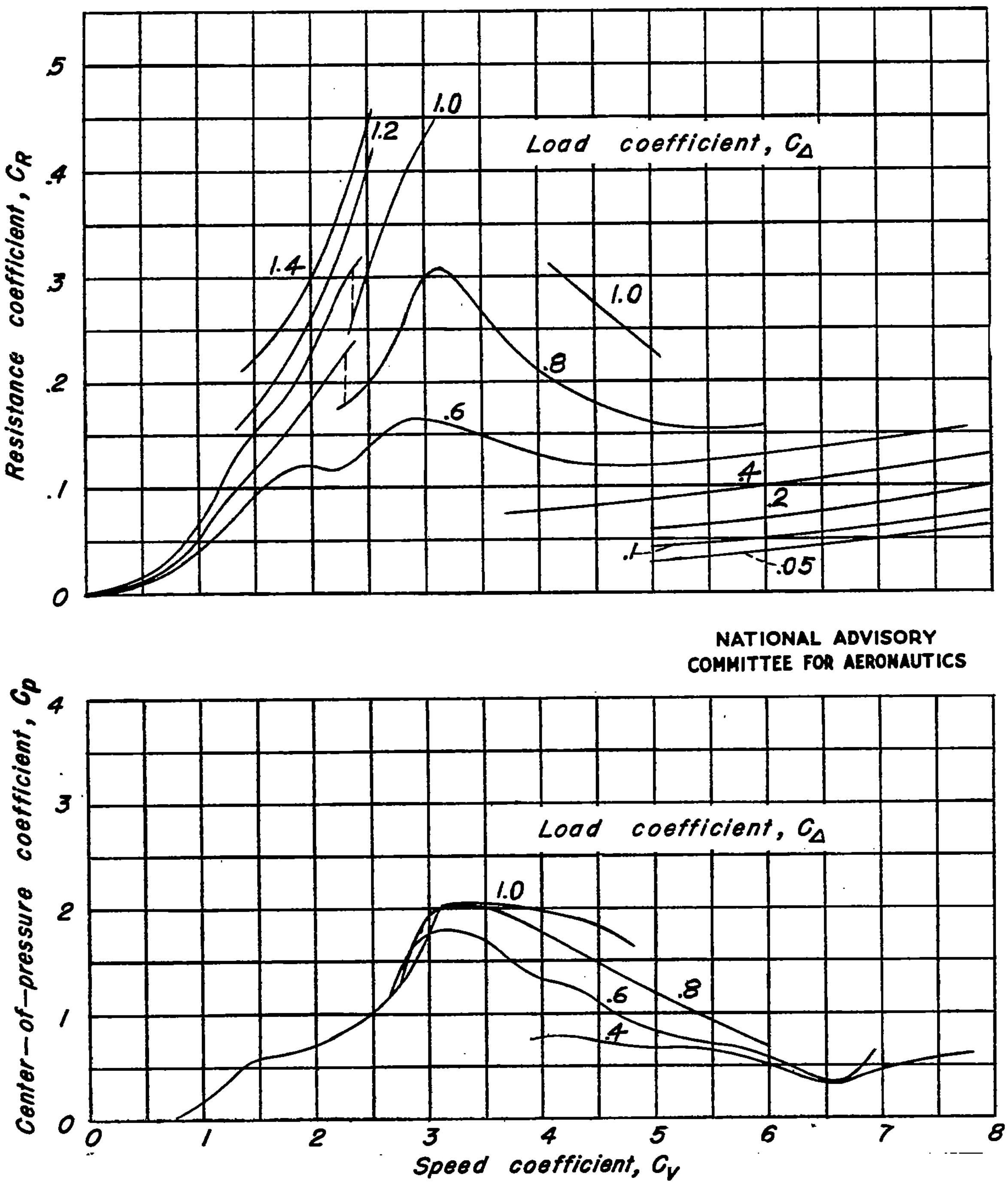
(i) Trim, 14°.

Figure 4.-Concluded.

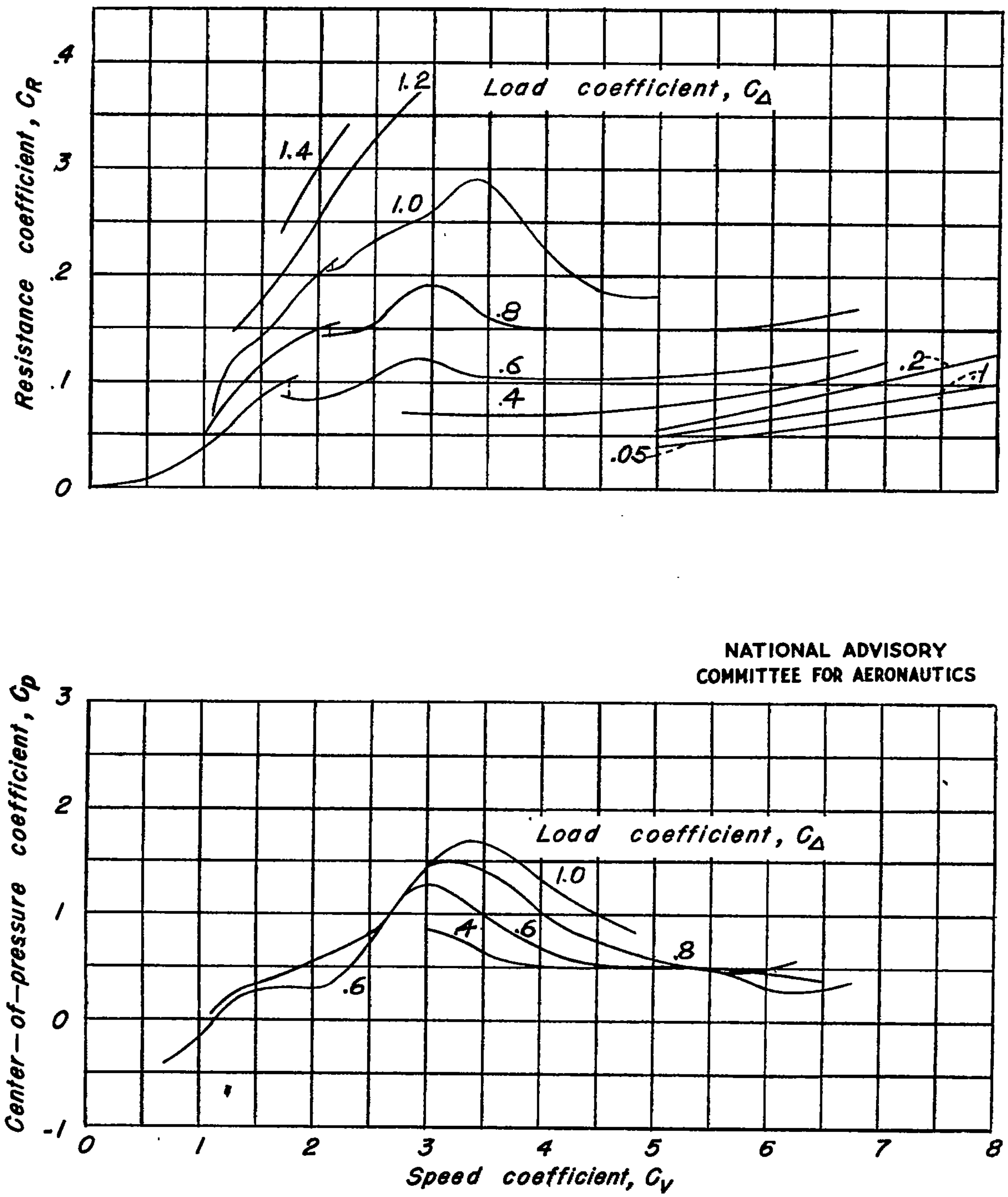


(a) Trim, 2°.

Figure 5.- Resistance and center of pressure. Model 175FA.

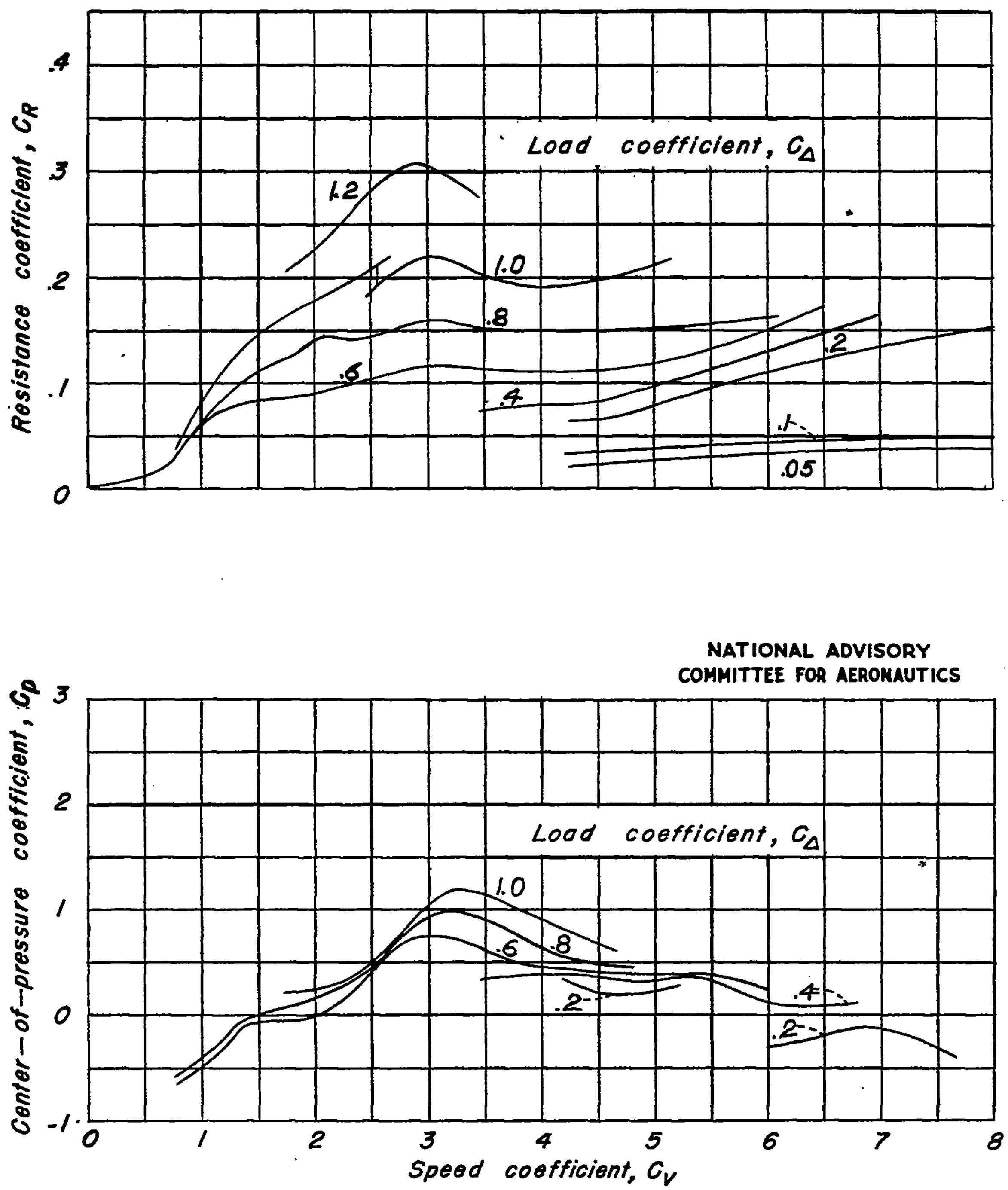


(b) Trim, 4°.
Figure 5.– Continued.

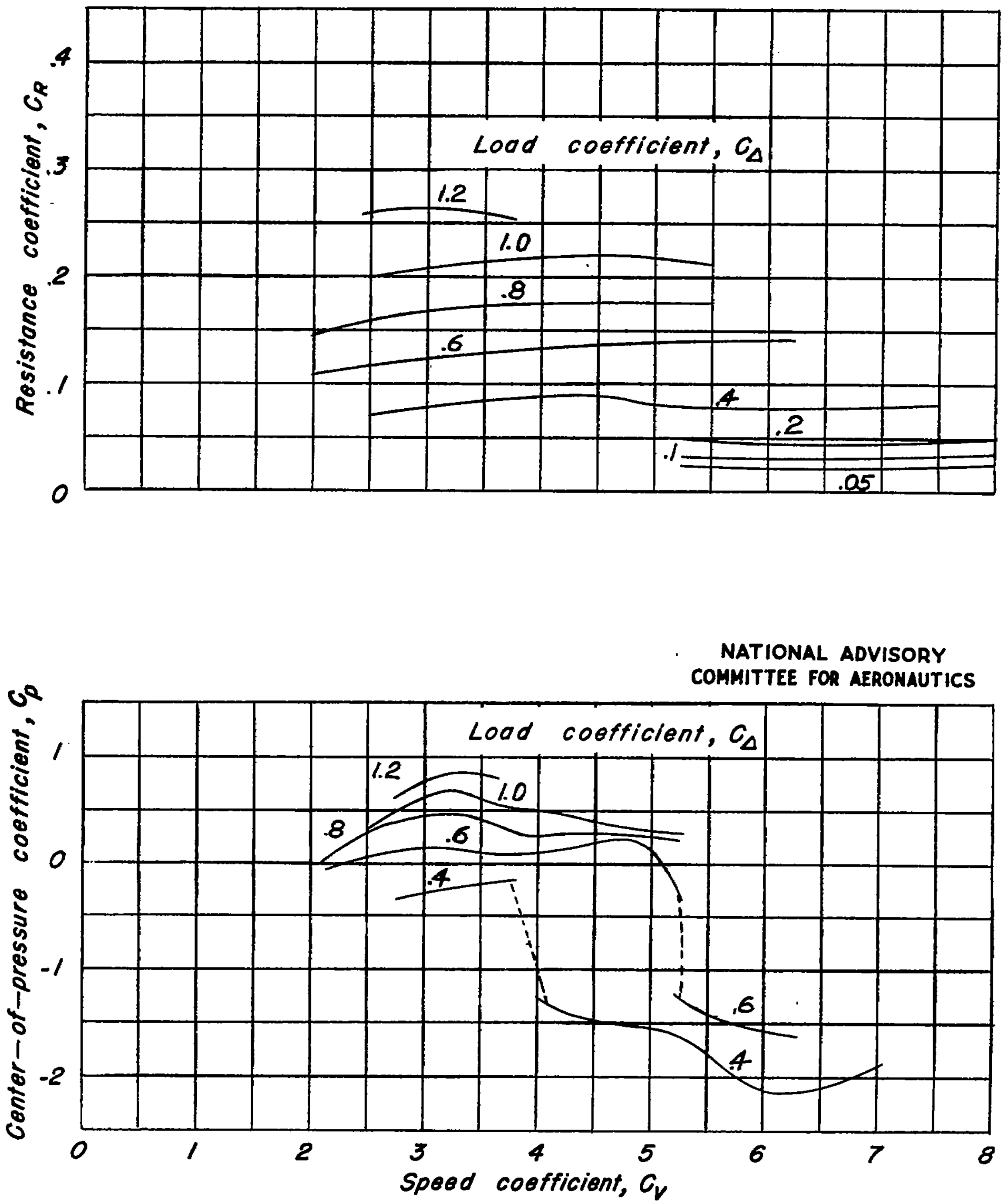


(c) Trim, 6°.

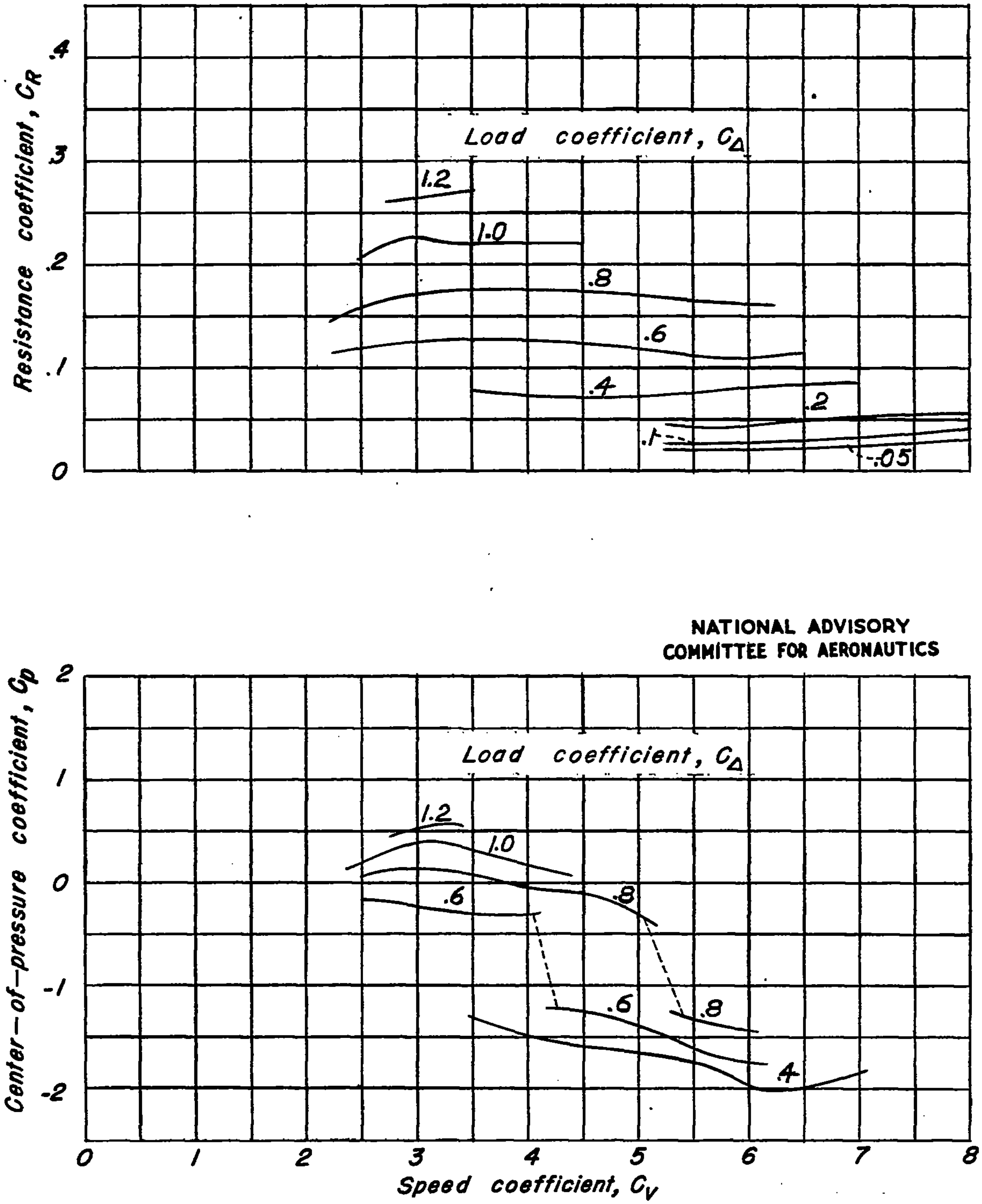
Figure 5.– Continued.



(d) Trim, 8°.
Figure 5.– Continued.

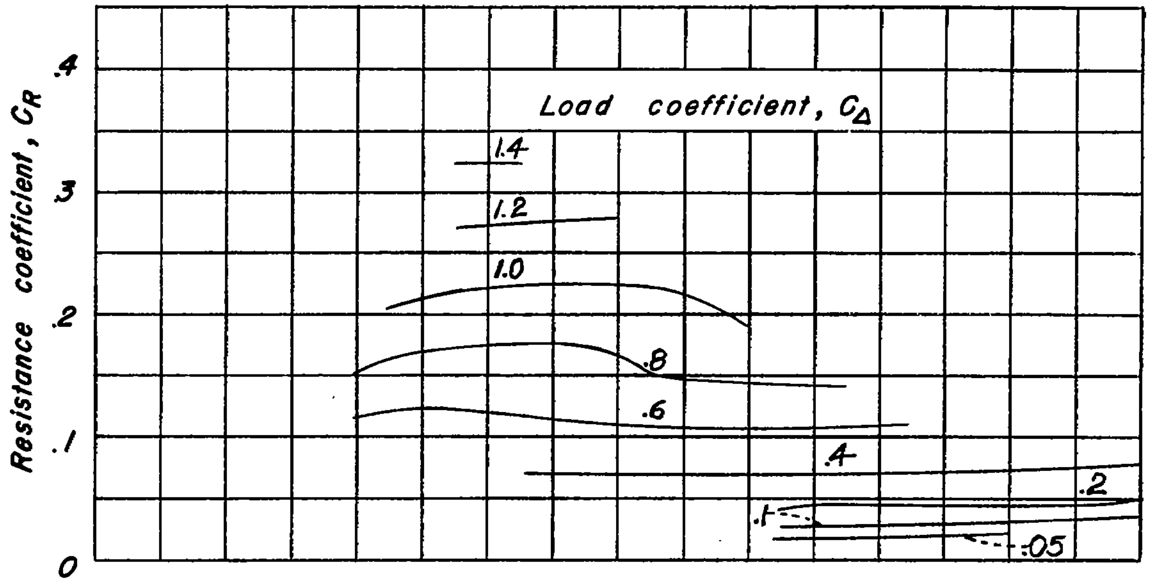


(e) Trim, 10°.
Figure 5.– Continued.



(f) Trim, 11°.

Figure 5.– Continued.



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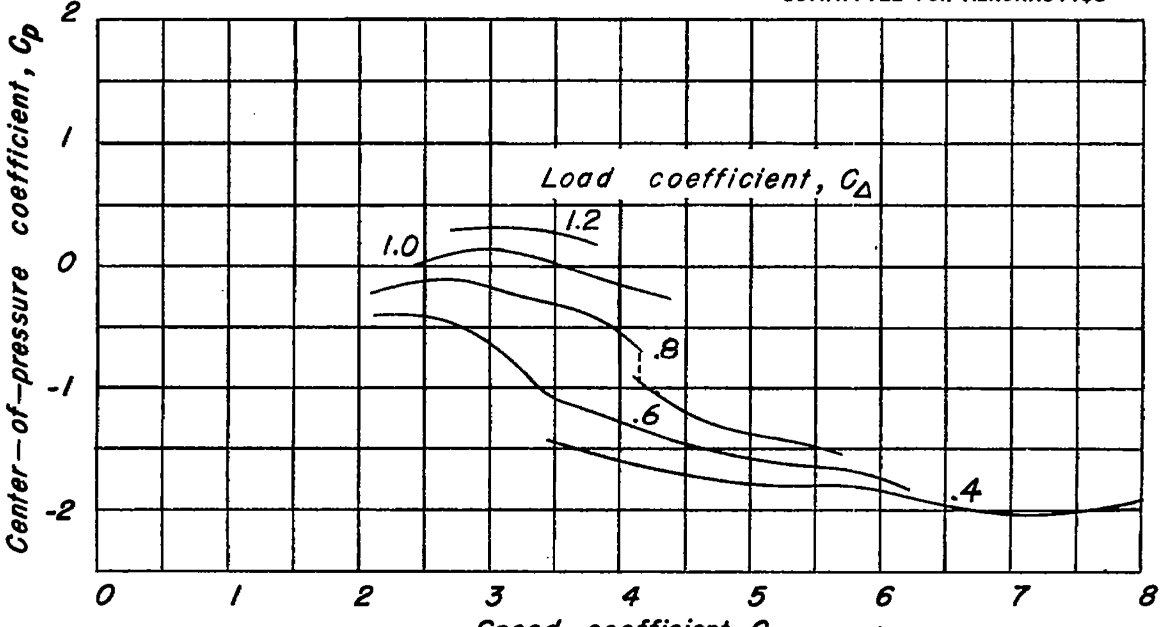
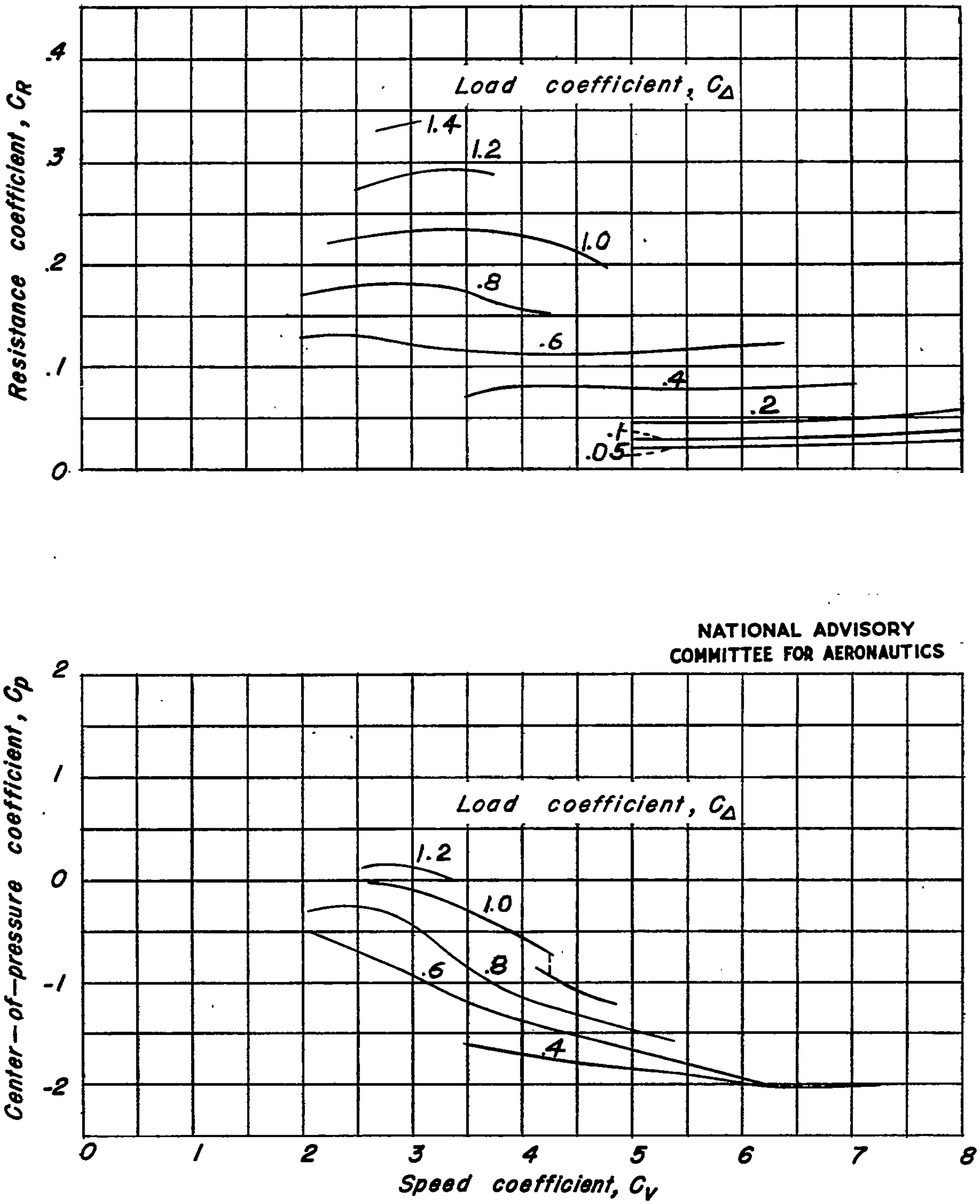


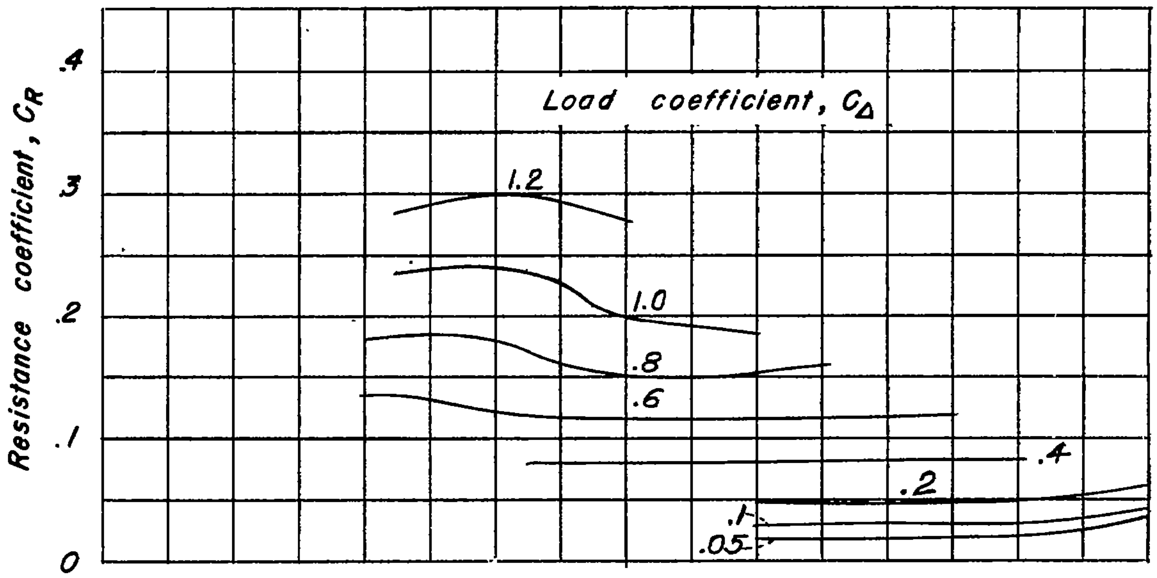
(g) Trim, 12°.

Figure 5.– Continued.



(h) Trim, 13°.

Figure 5.– Continued.



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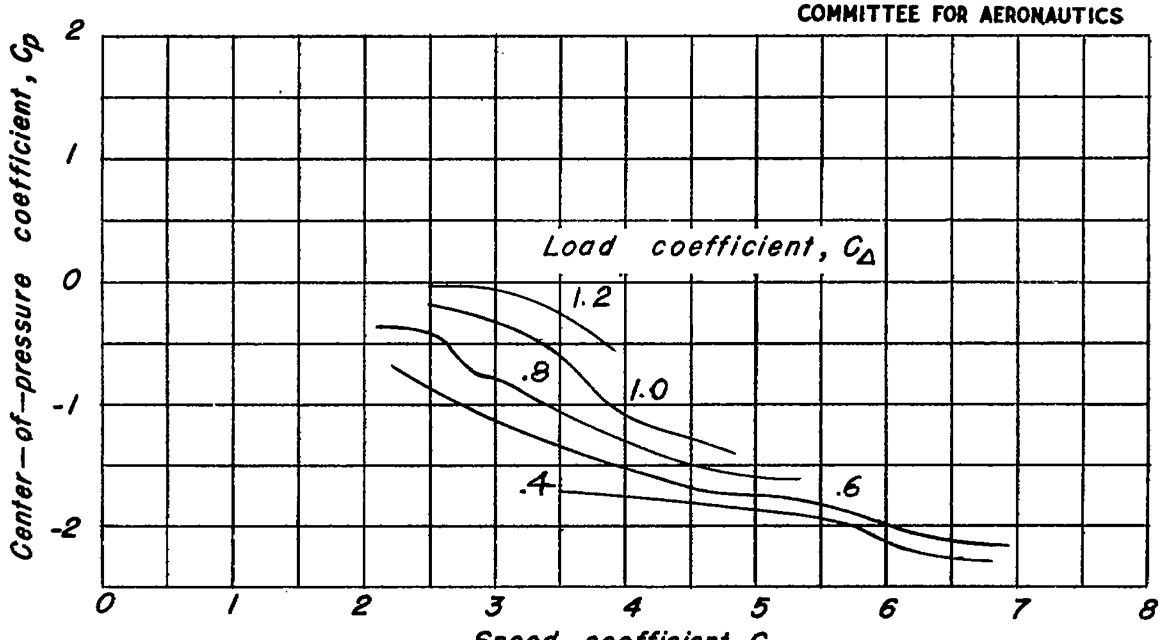
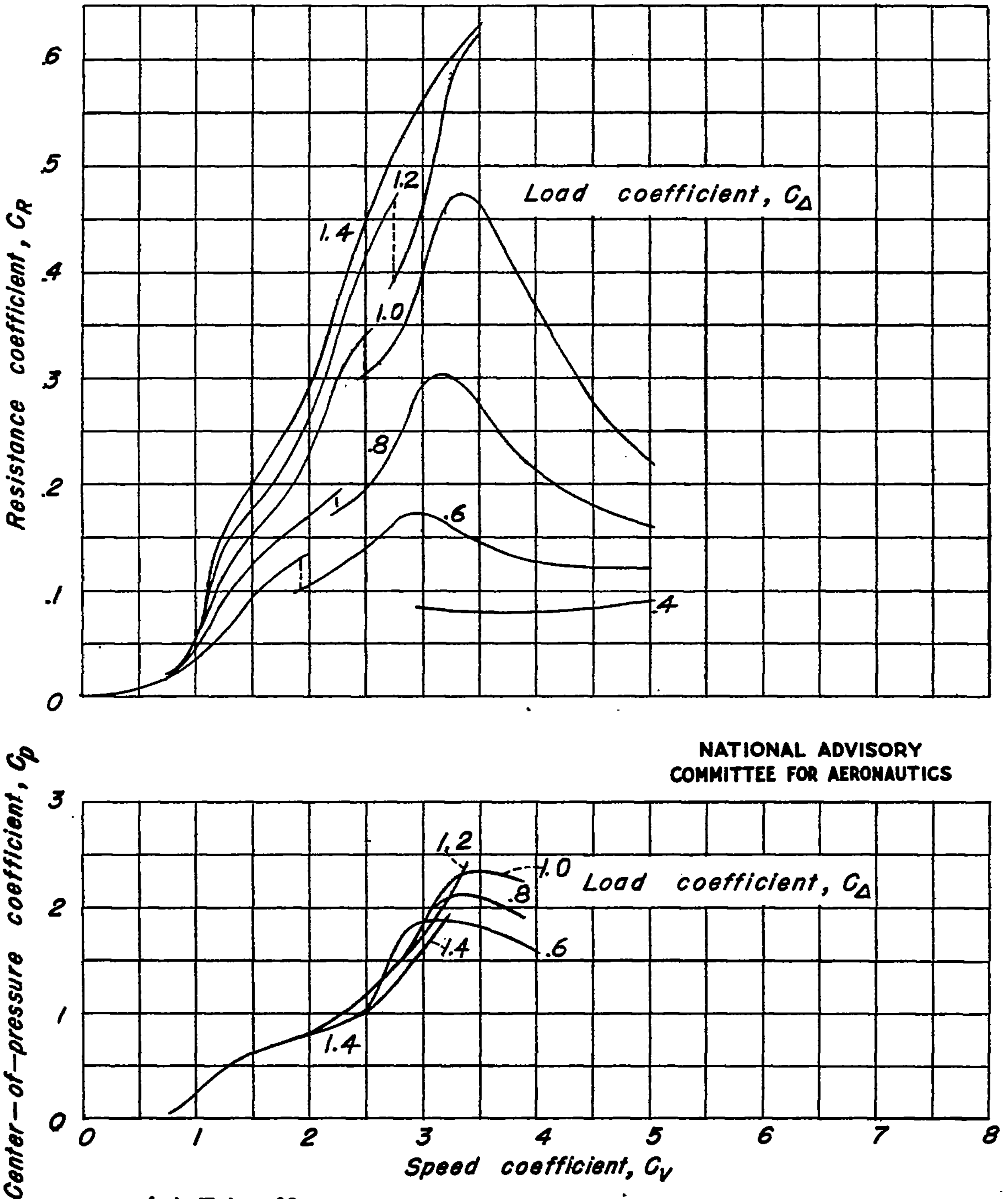


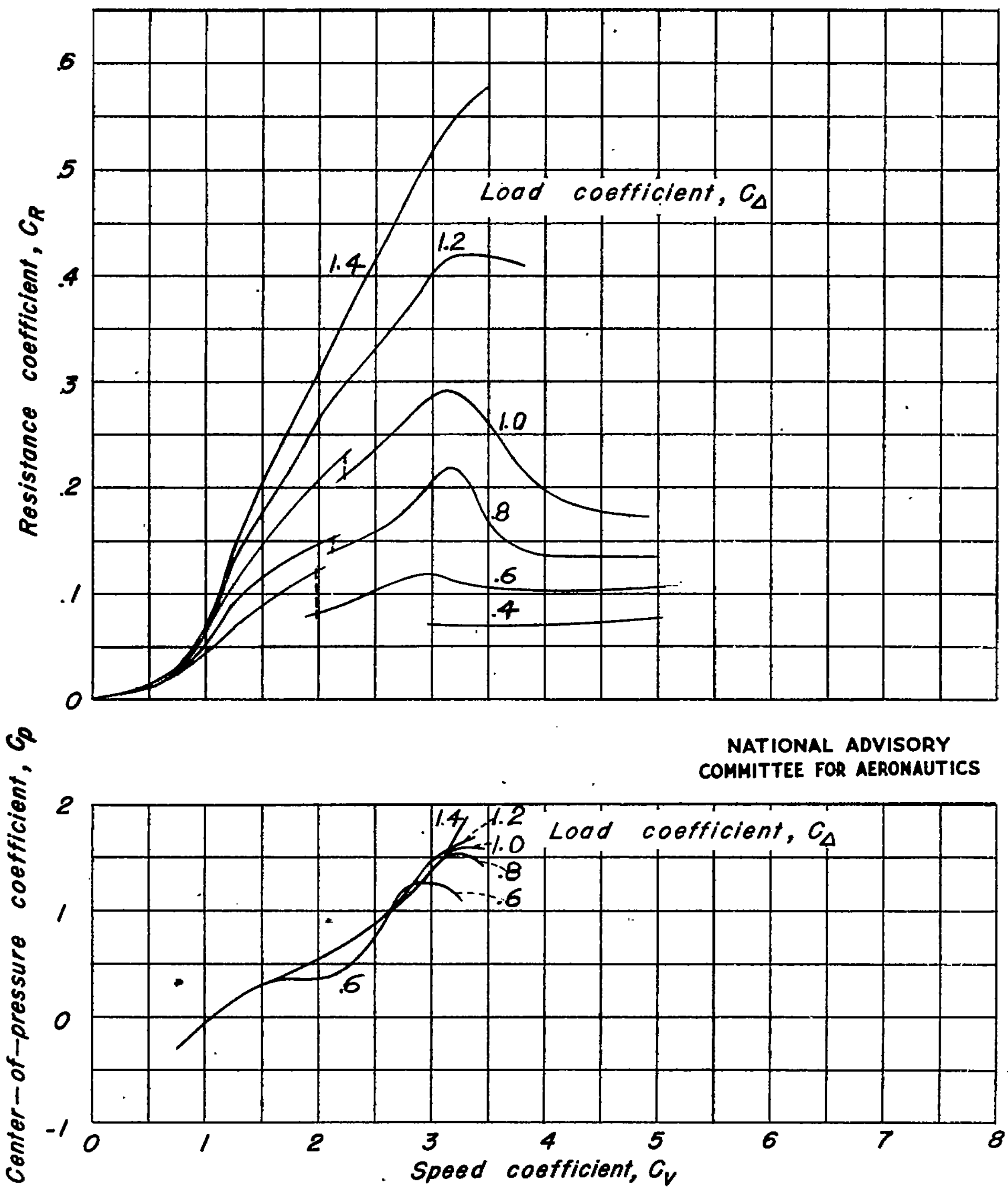
(i) Trim, 14°.

Figure 5.– Concluded.



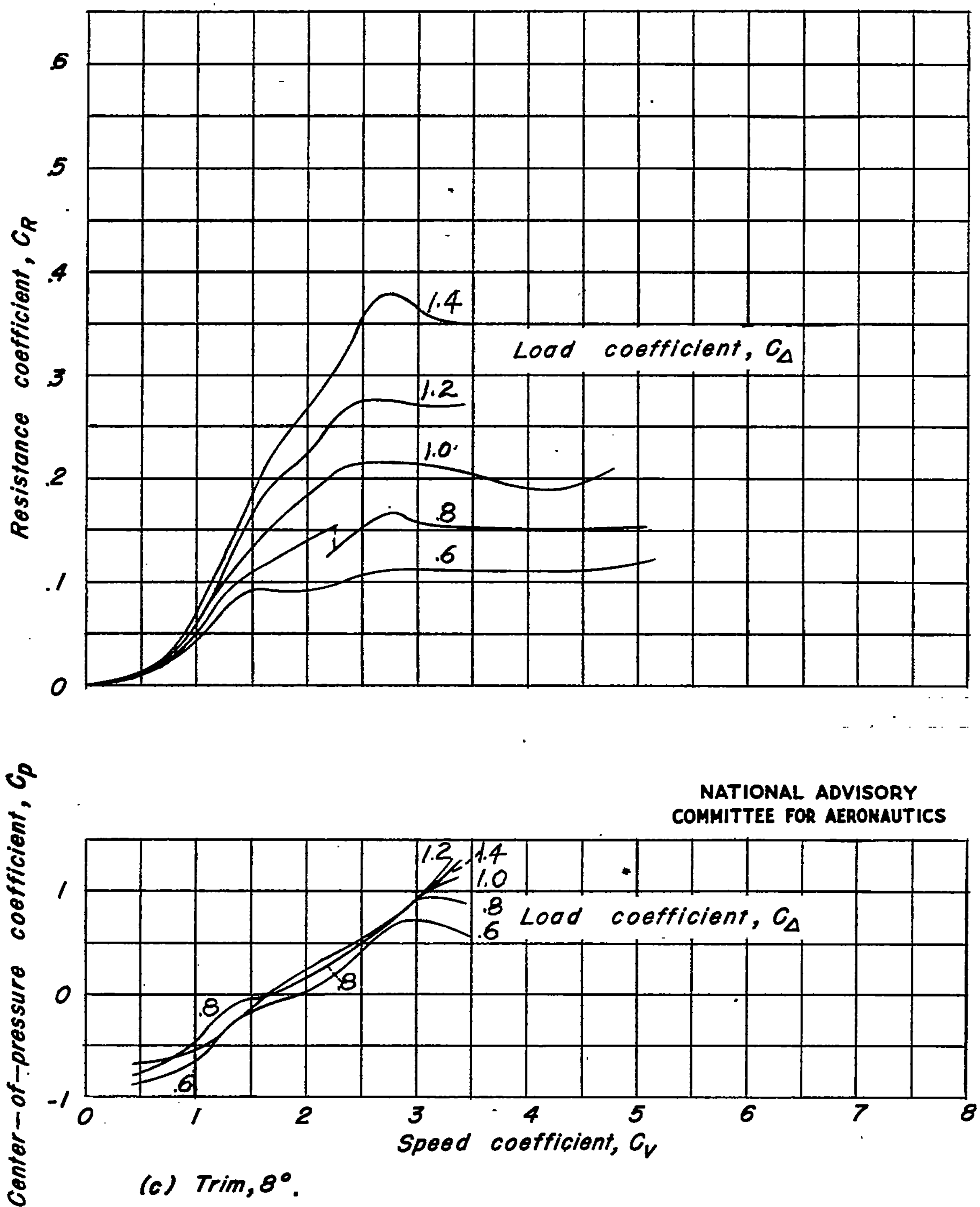
(a) Trim, 4°.

Figure 6.– Resistance and center of pressure. Model 175FAT.

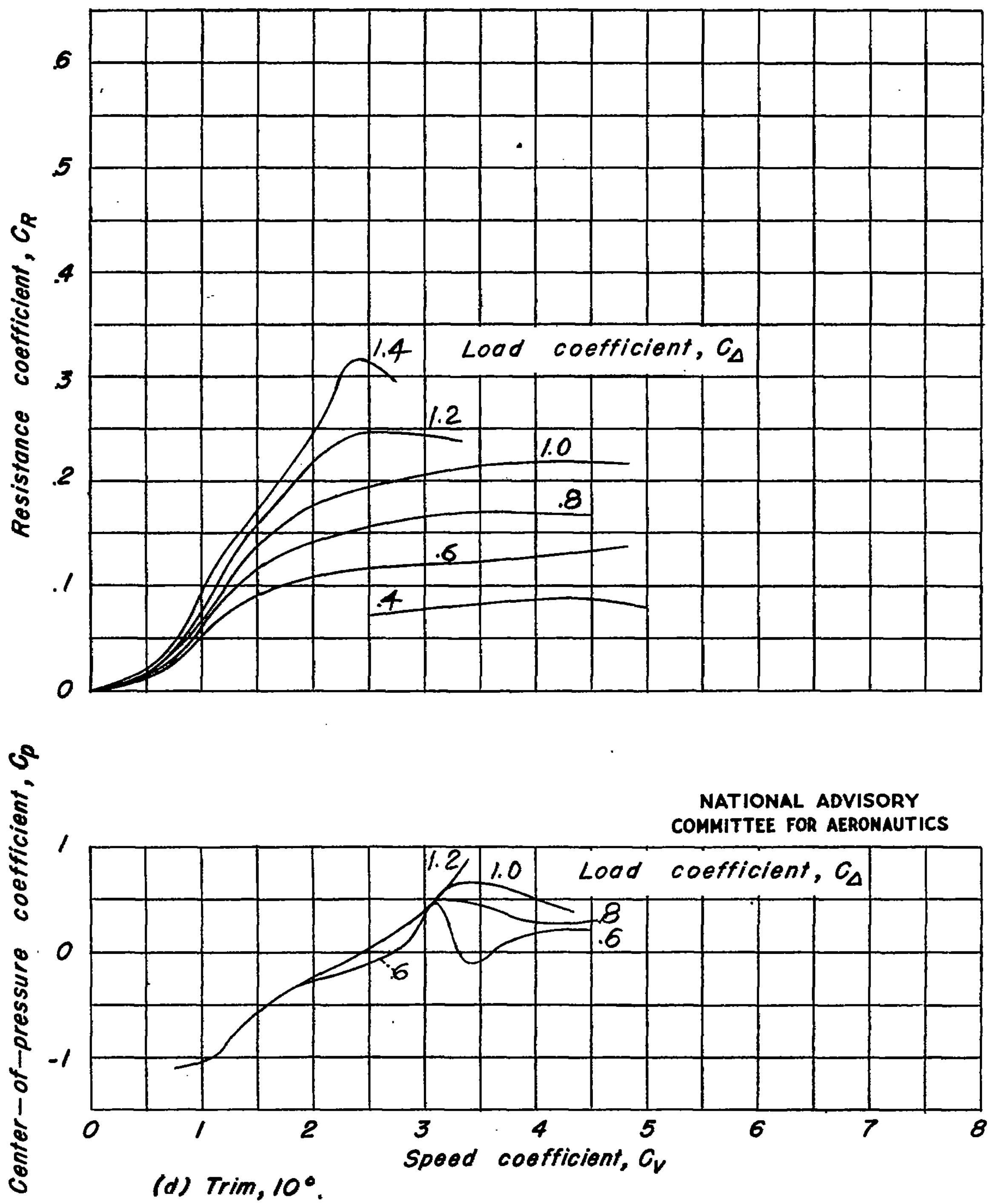


(b) Trim, 6°.

Figure 6.– Continued.

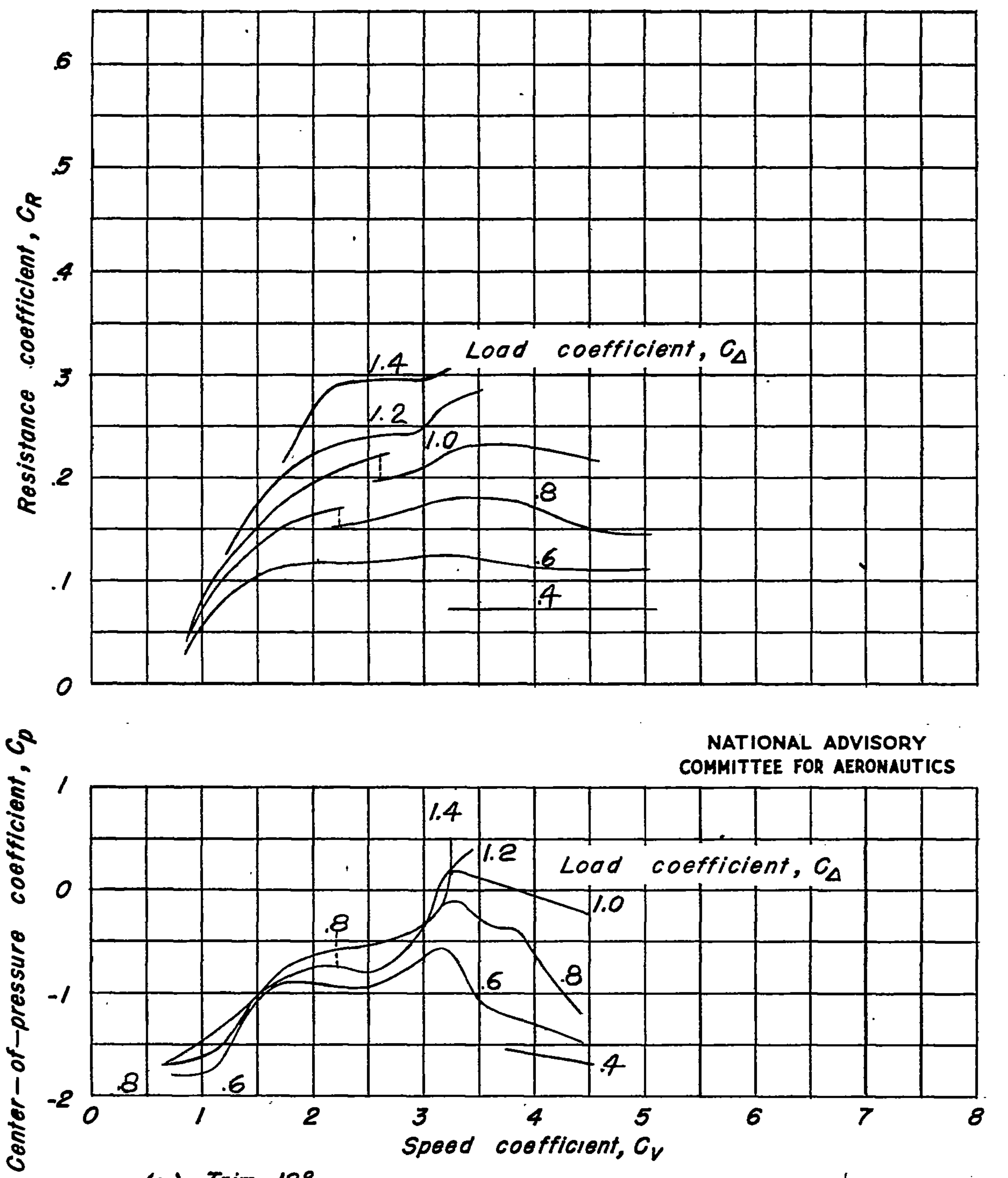


(c) Trim, 8°.
Figure 6.- Continued.



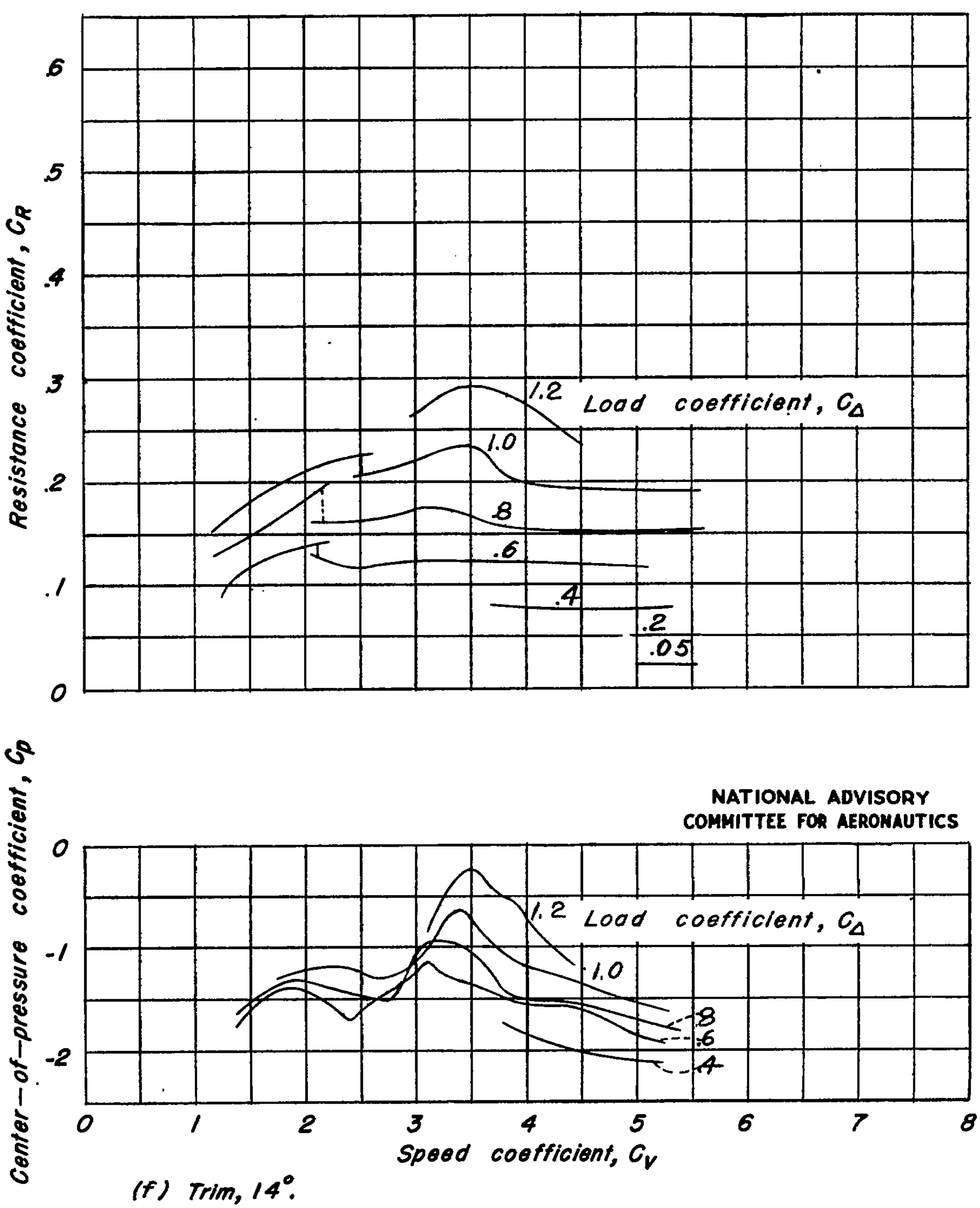
(d) Trim, 10°.

Figure 6.– Continued.



(e) Trim, 12°.

Figure 6.- Continued.



(f) Trim, 14°.

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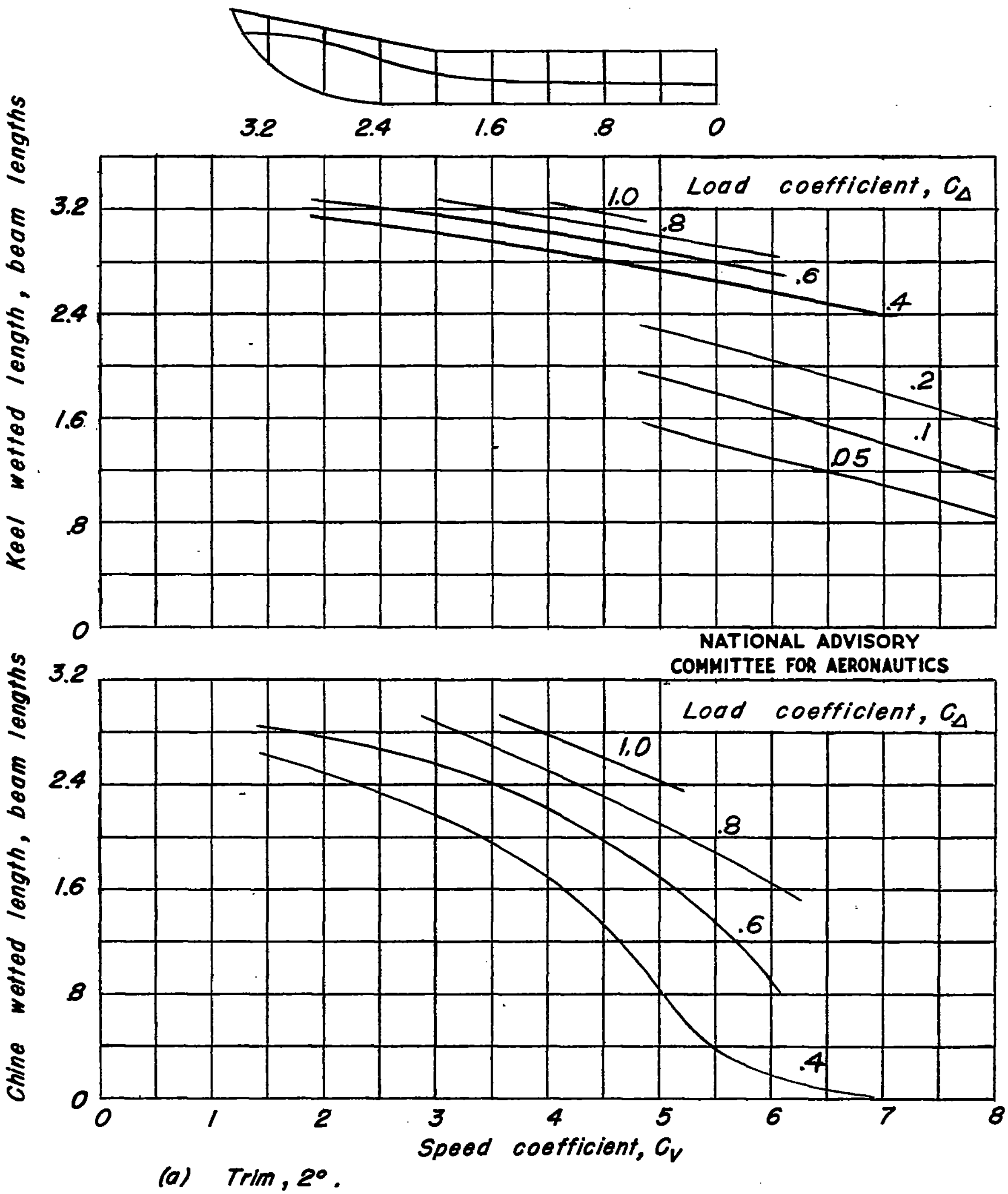
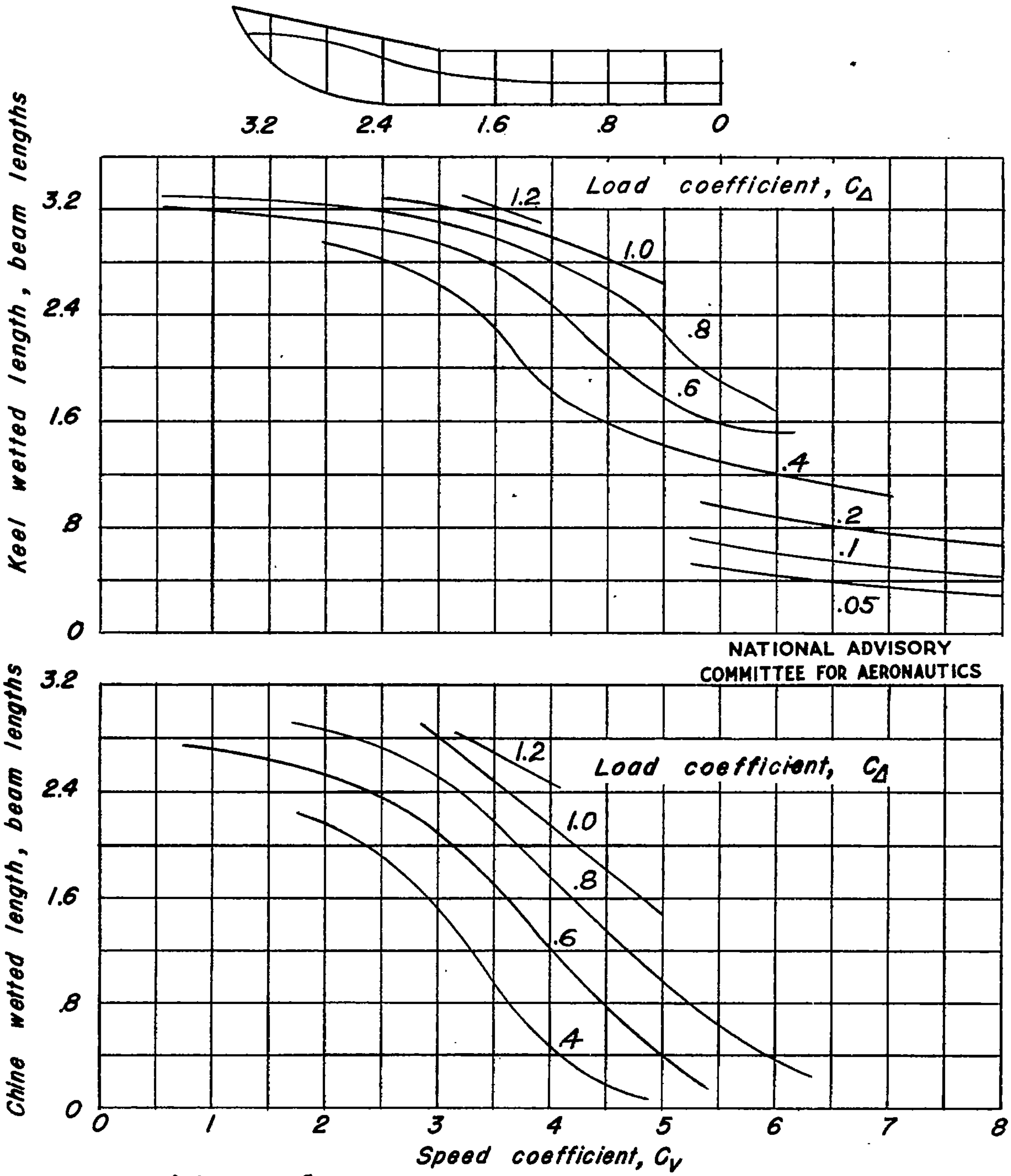


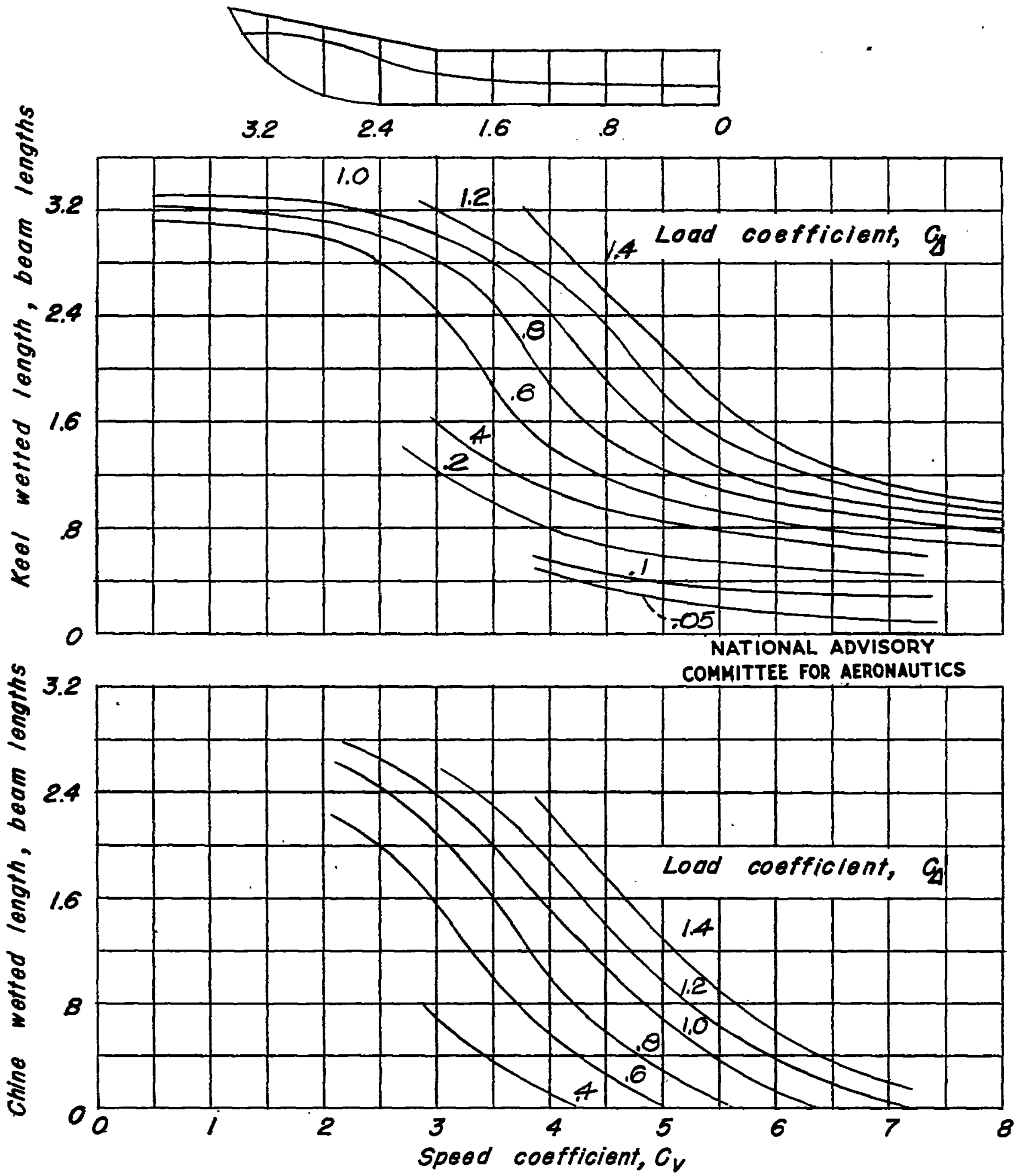
(a) Trim, 2°.

Figure 7.– Forebody keel and chine wetted lengths. Model 175 F.



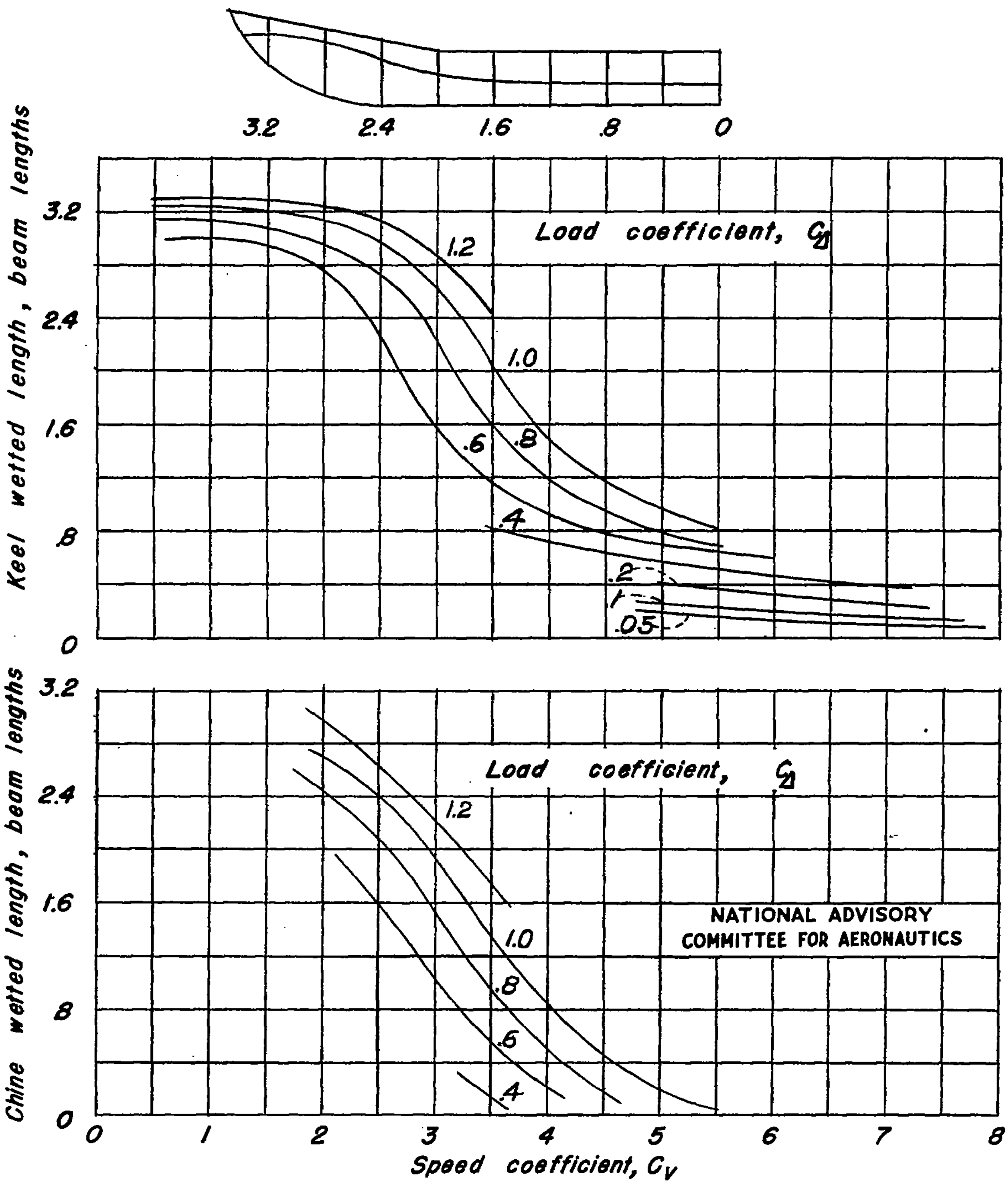
(b) Trim, 4°.

Figure 7.- Continued.



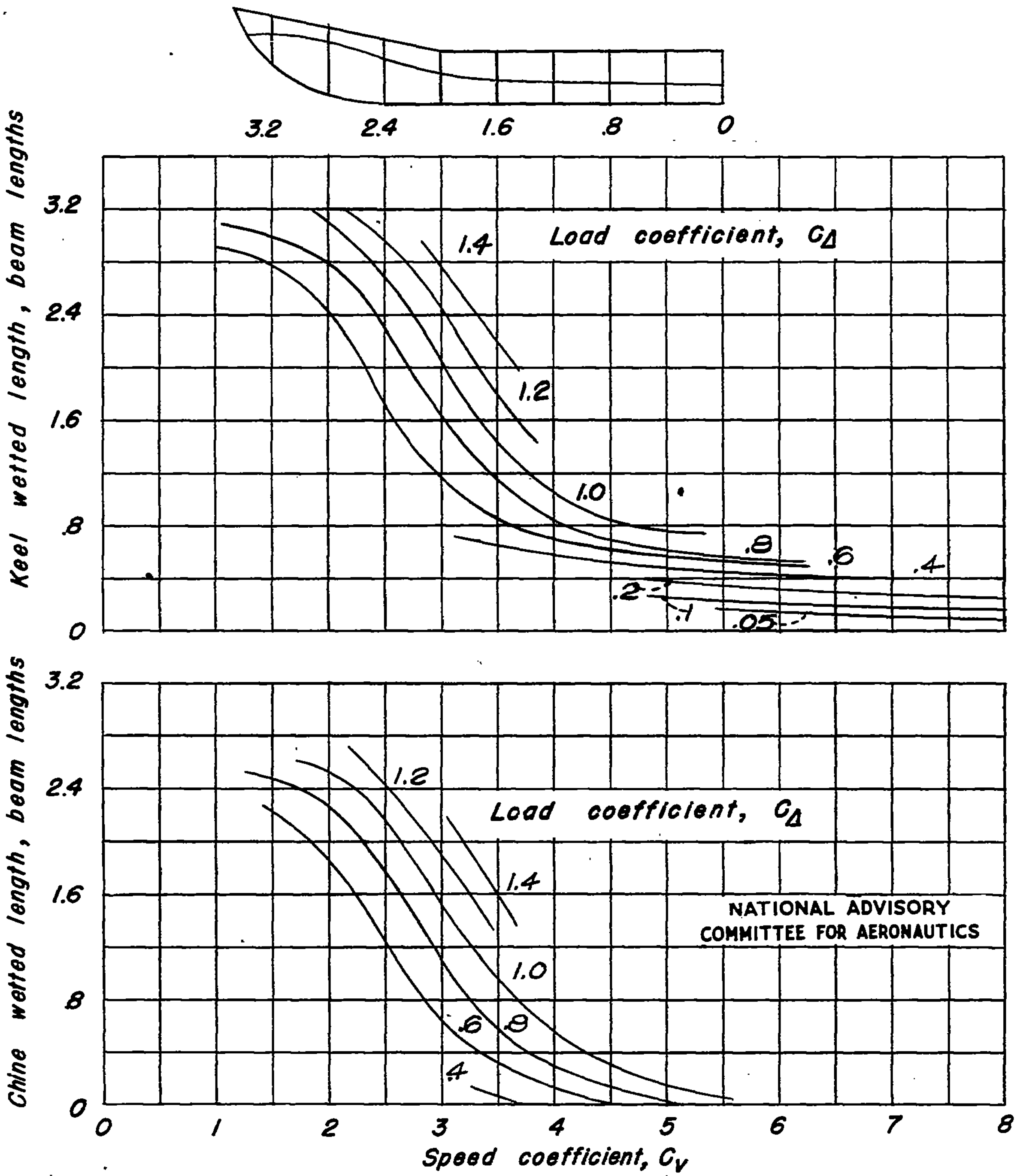
(c) Trim, 6°.

Figure 7.- Continued.



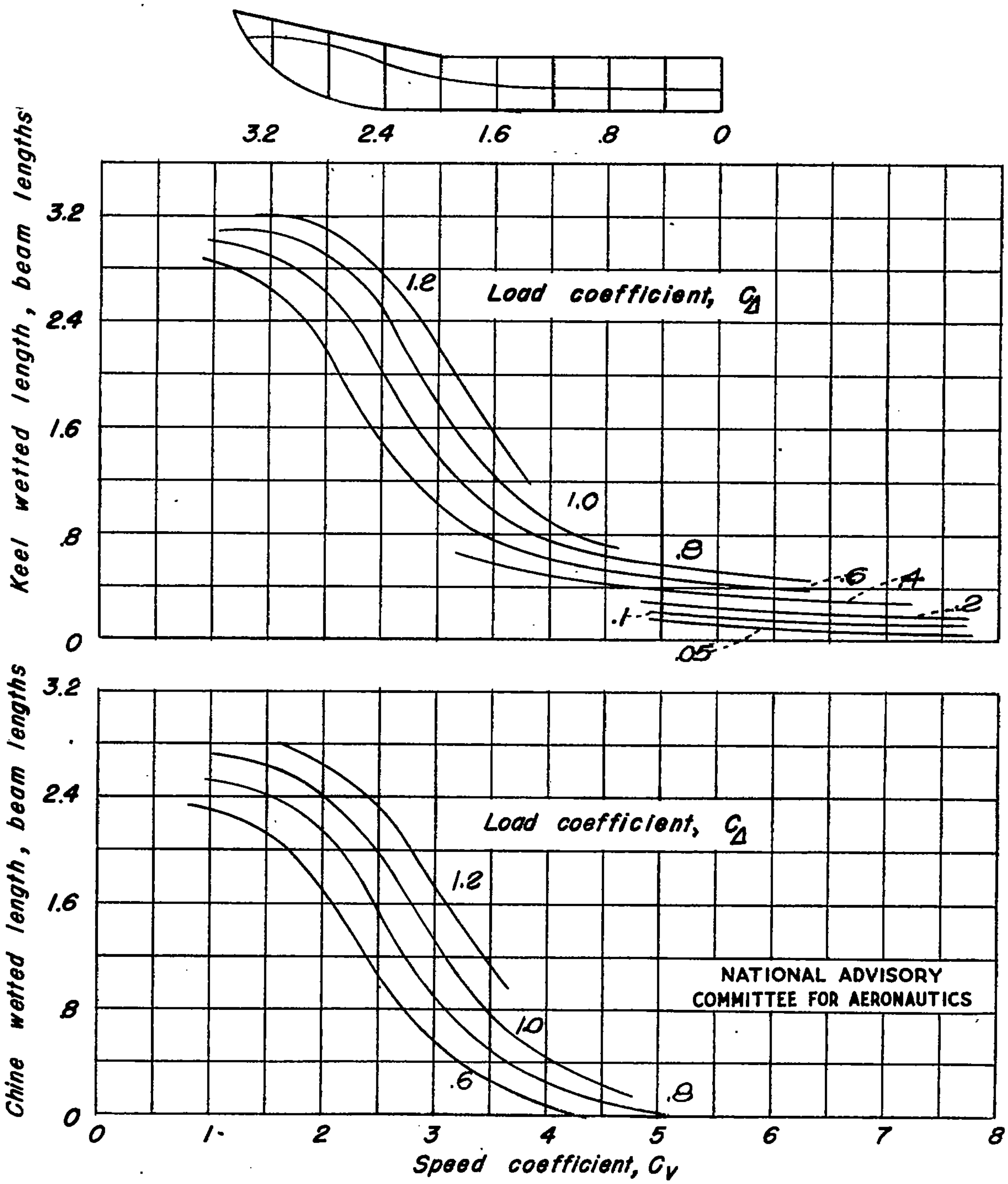
(d) Trim, 8°.

Figure 7.- Continued.



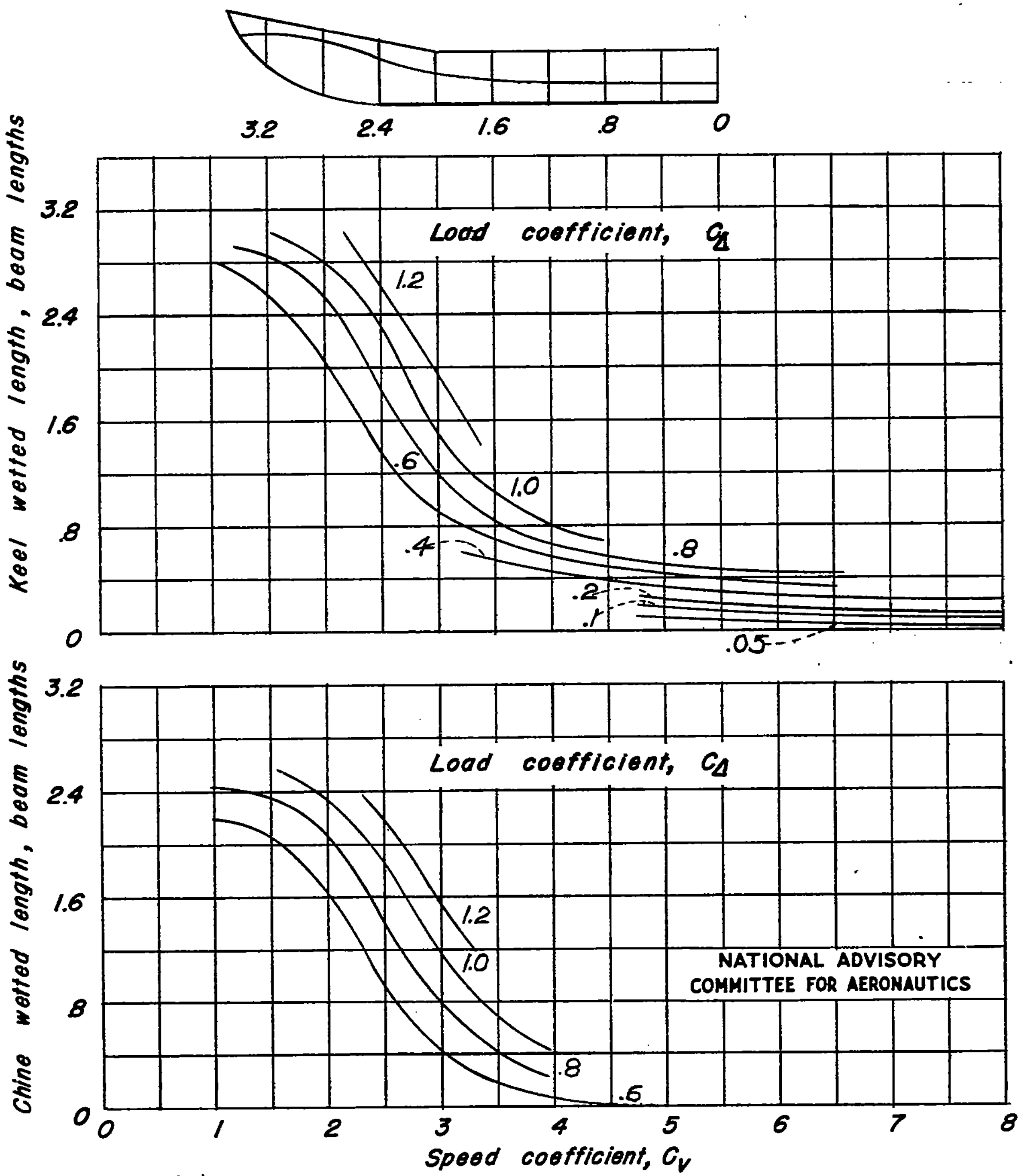
(e) Trim, 10°.

Figure 7.– Continued.



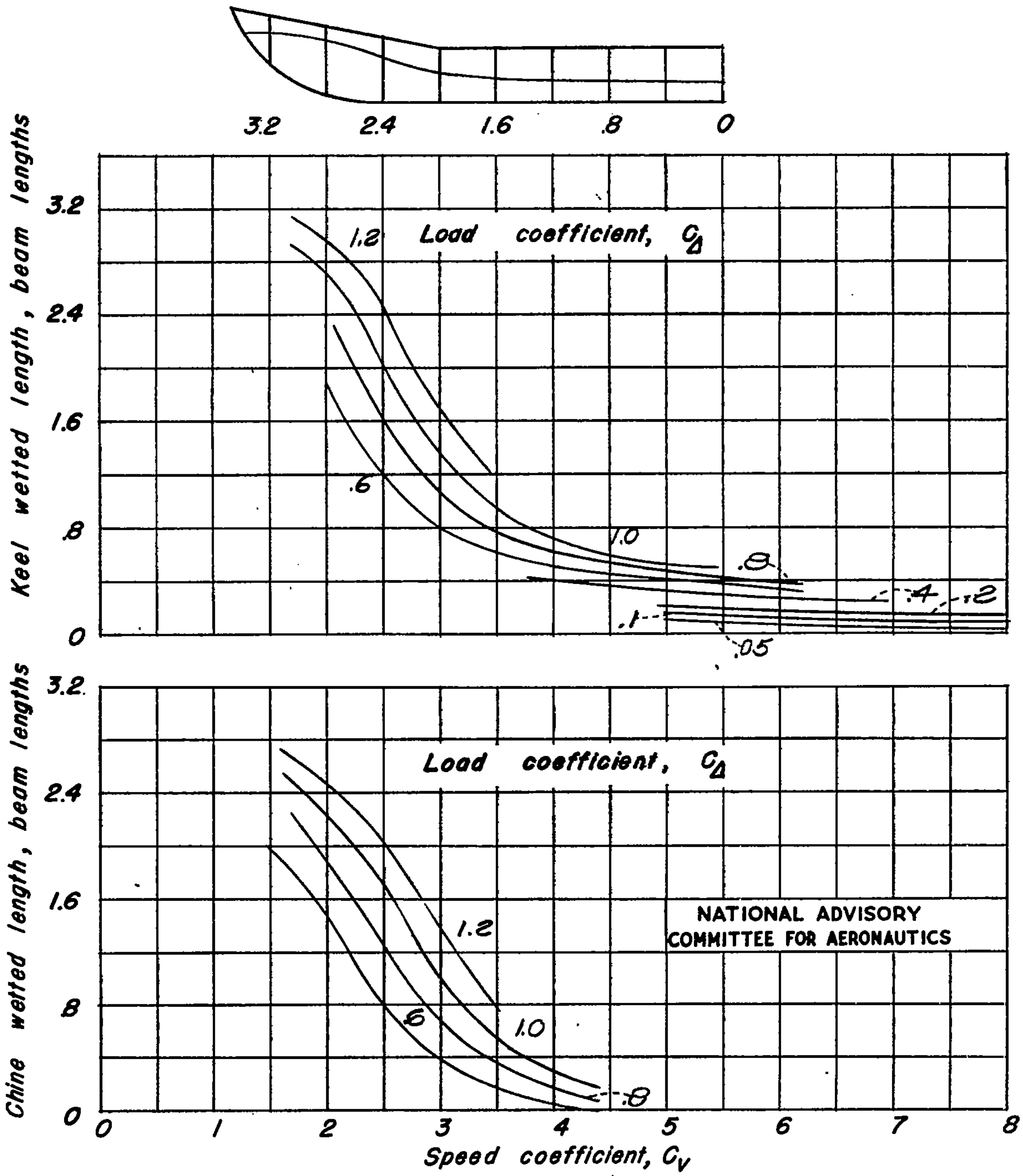
(f) Trim, 11°.

Figure 7.– Continued.



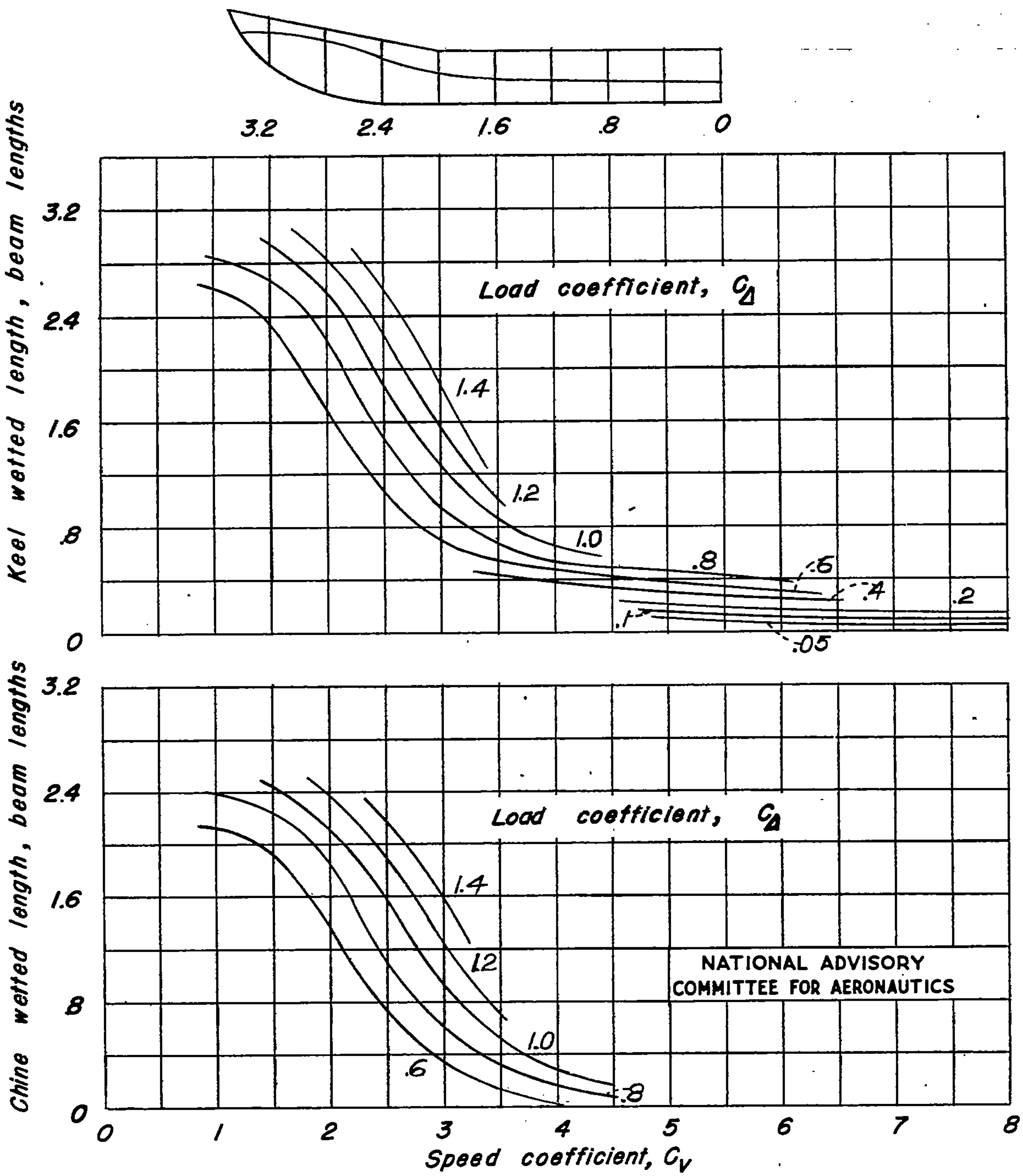
(g) Trim, 12°.

Figure 7.– Continued.



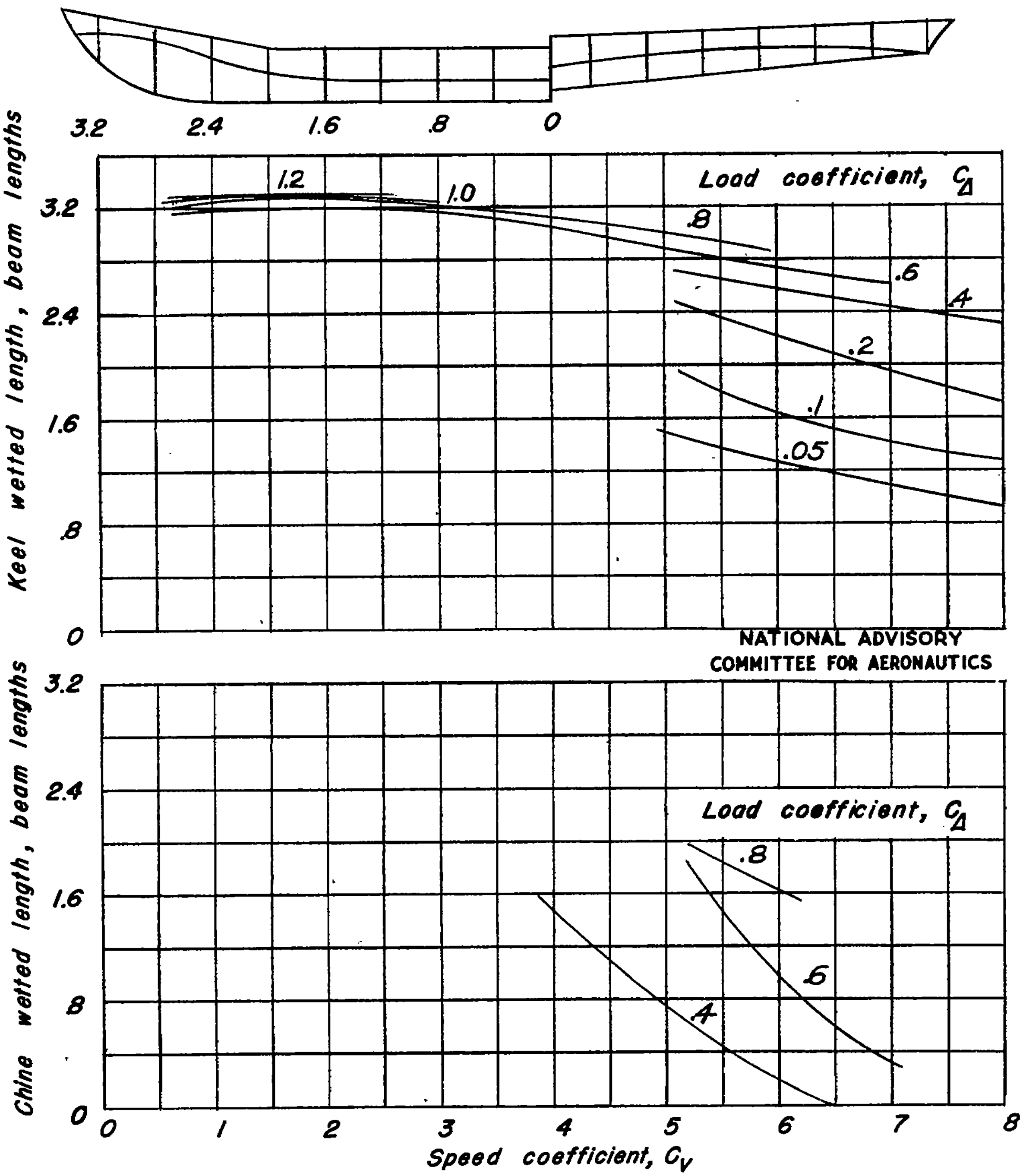
(h) Trim, 13°.

Figure 7.– Continued.



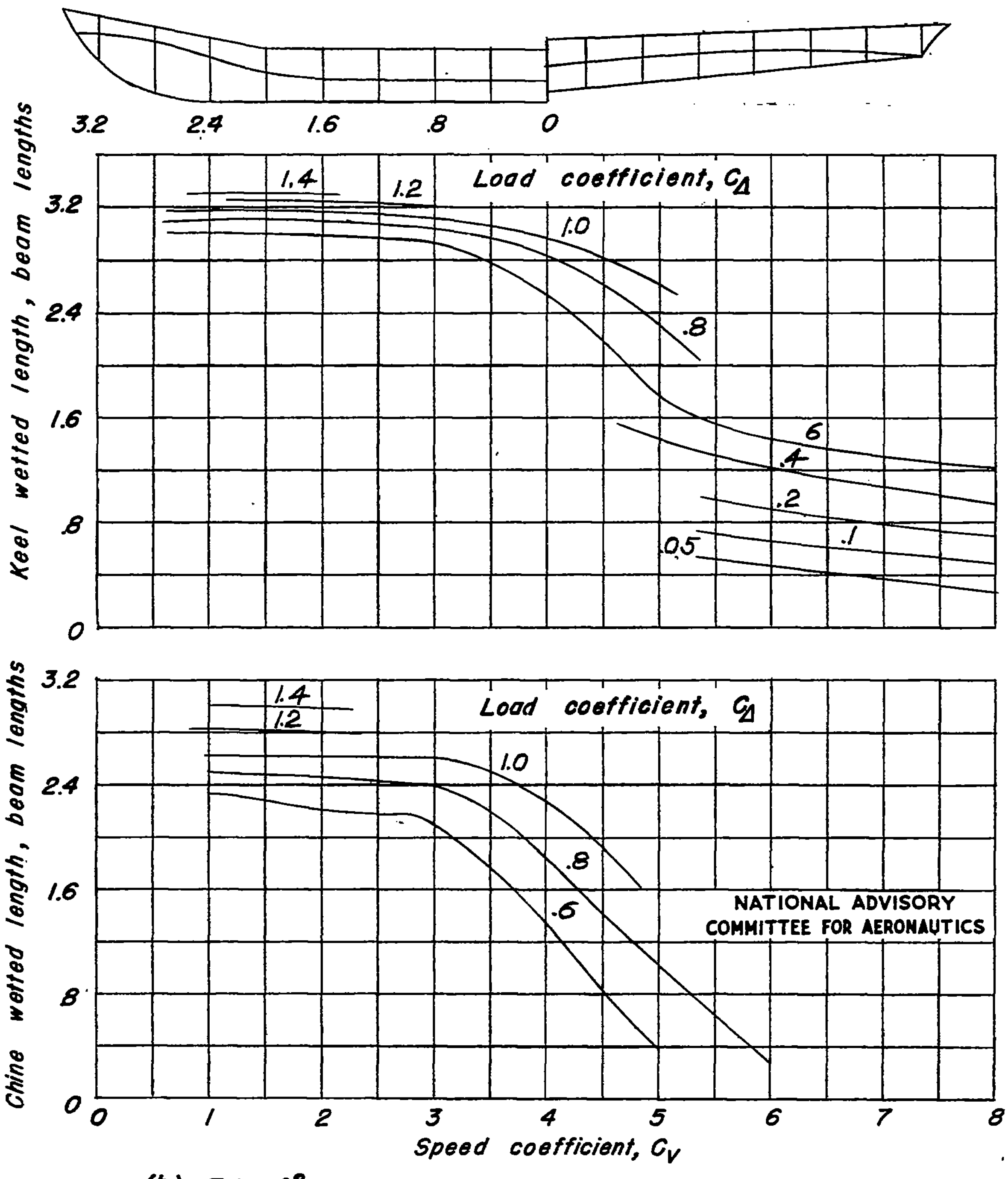
(i) Trim, 14°.

Figure 7.– Concluded.



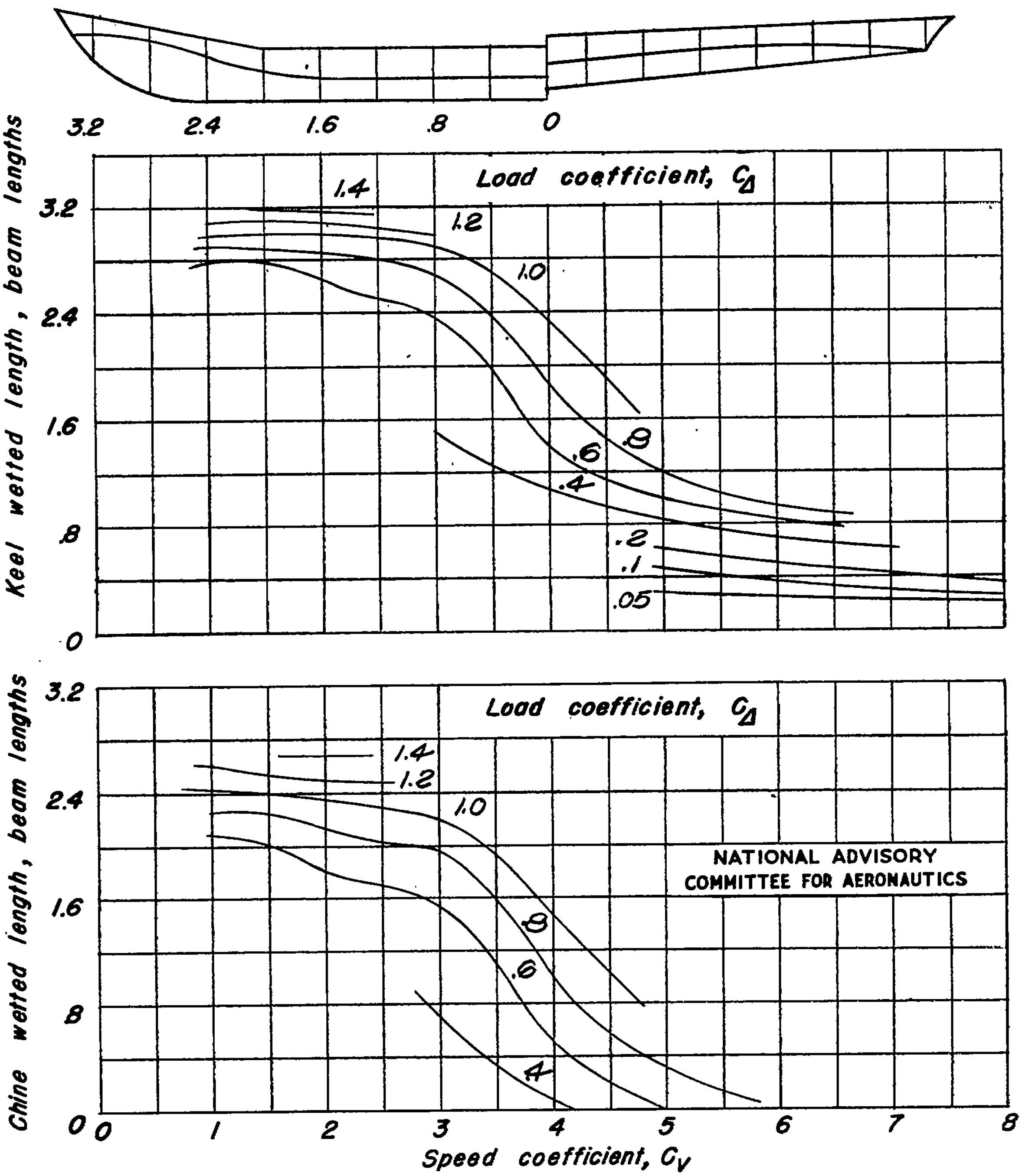
(a) Trim, 2°.

Figure 8.– Forebody keel and chine wetted lengths. Model 175 FA.



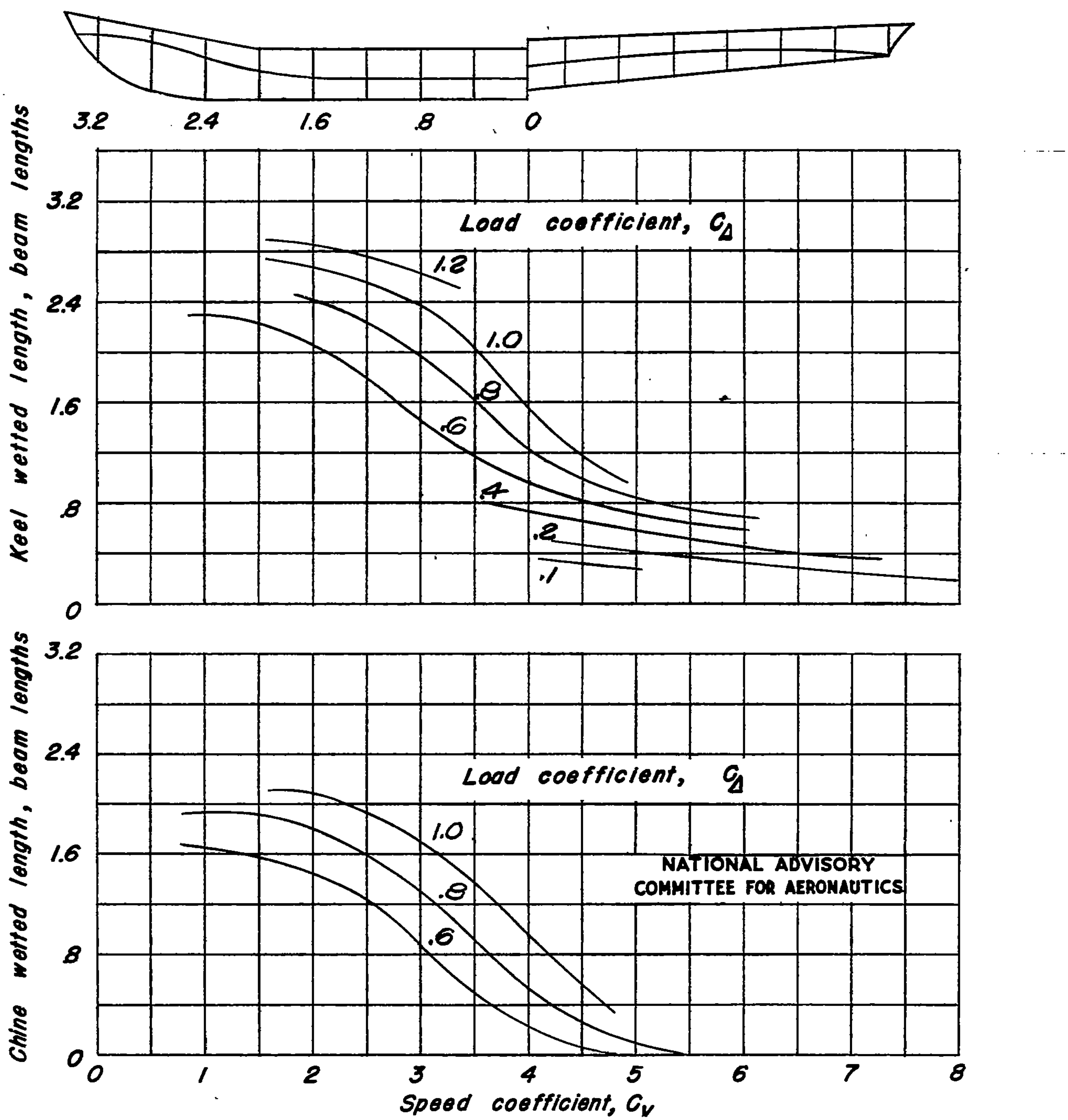
(b) Trim, 4°.

Figure 8.– Continued.



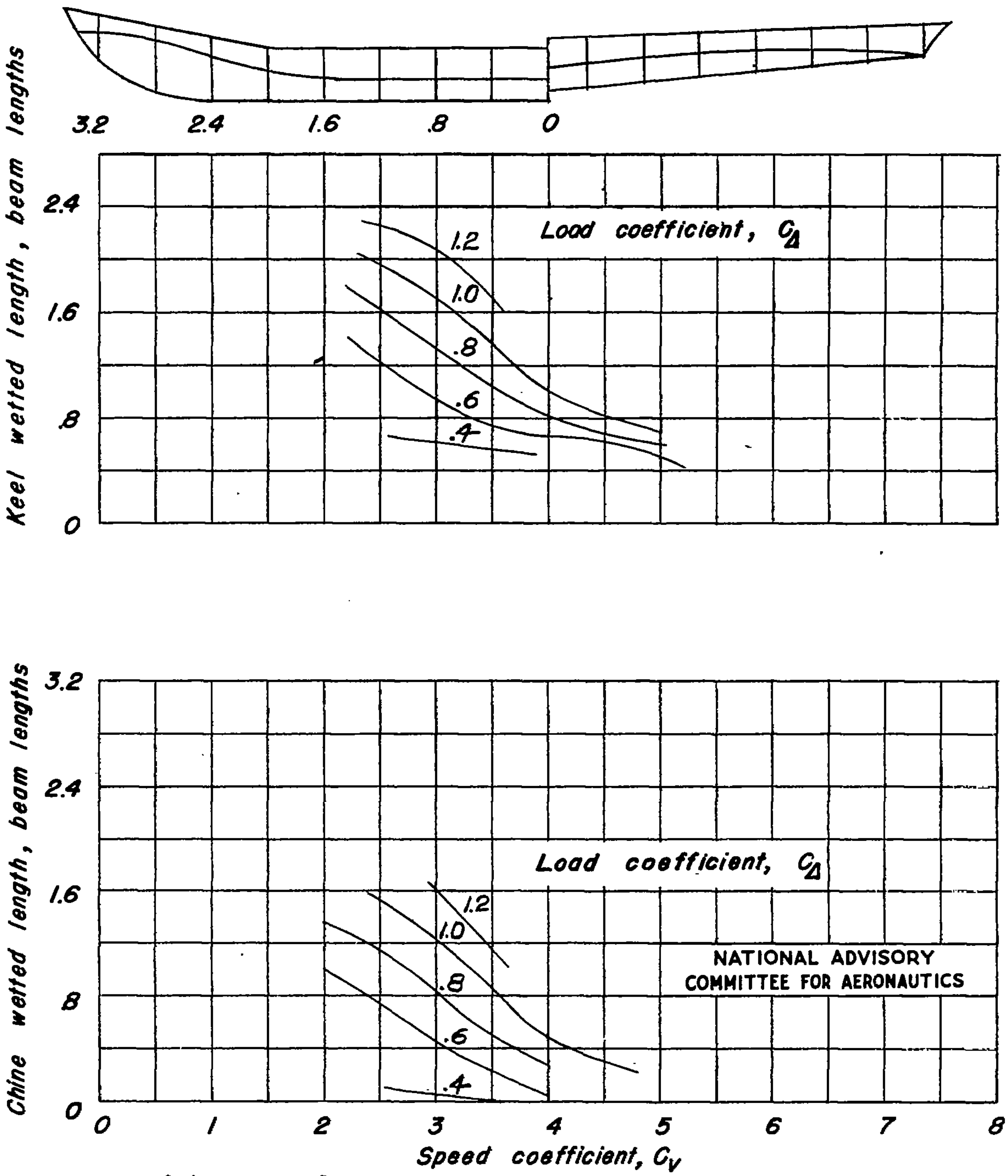
(c) Trim, 6°.

Figure 8.- Continued.



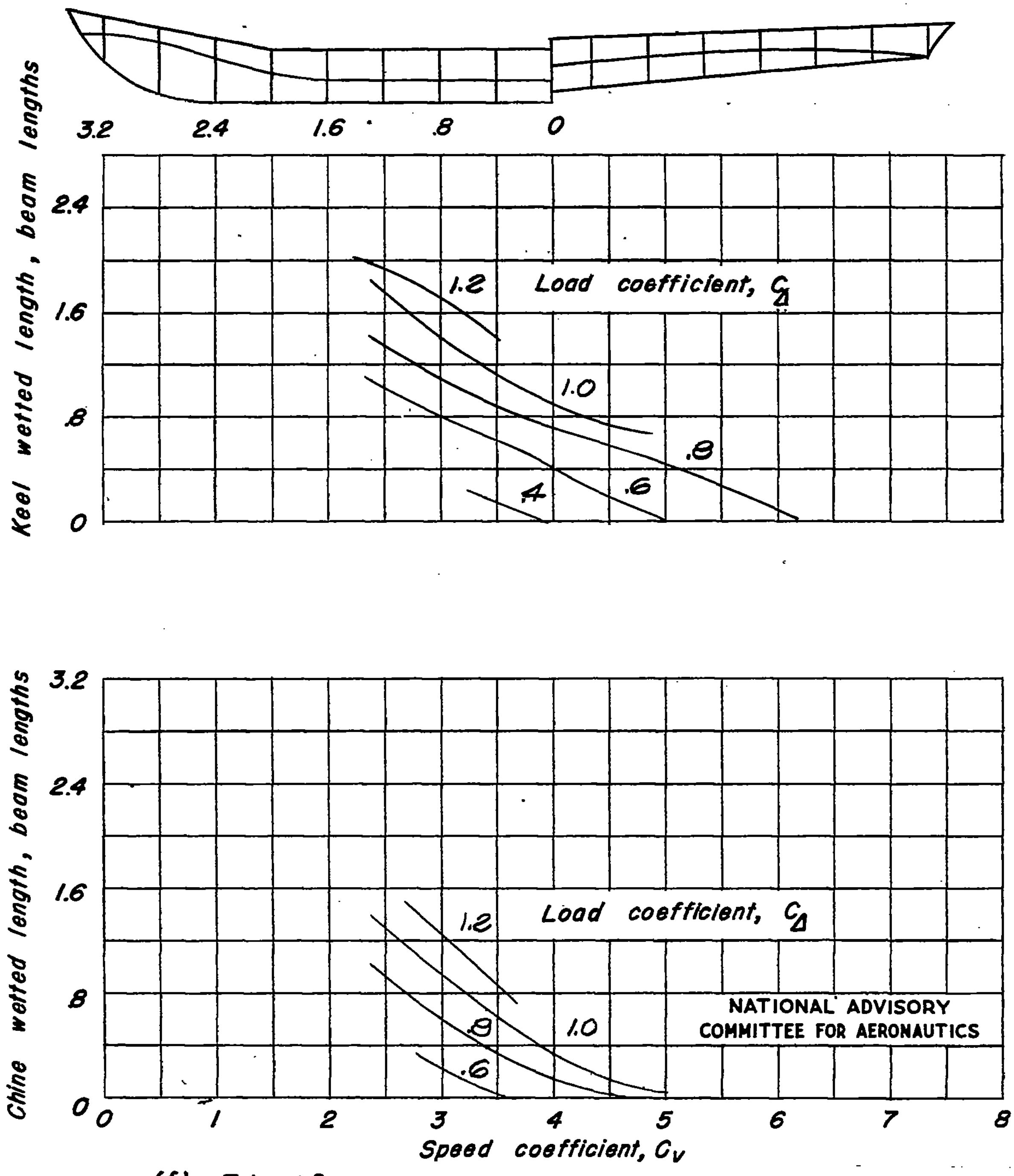
(d) Trim, 8°.

Figure 8.– Continued.



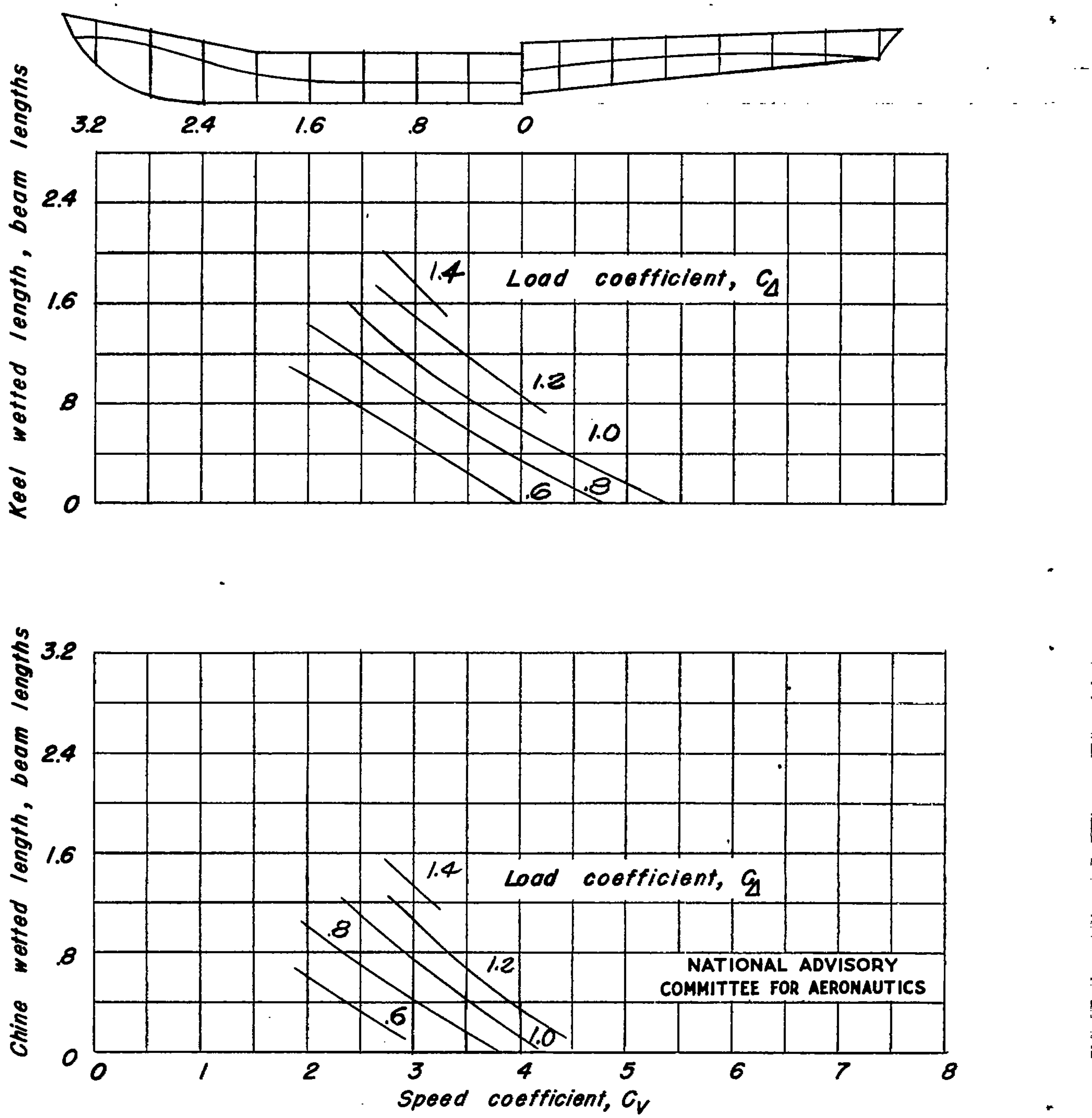
(e) Trim, 10°.

Figure 8.- Continued.



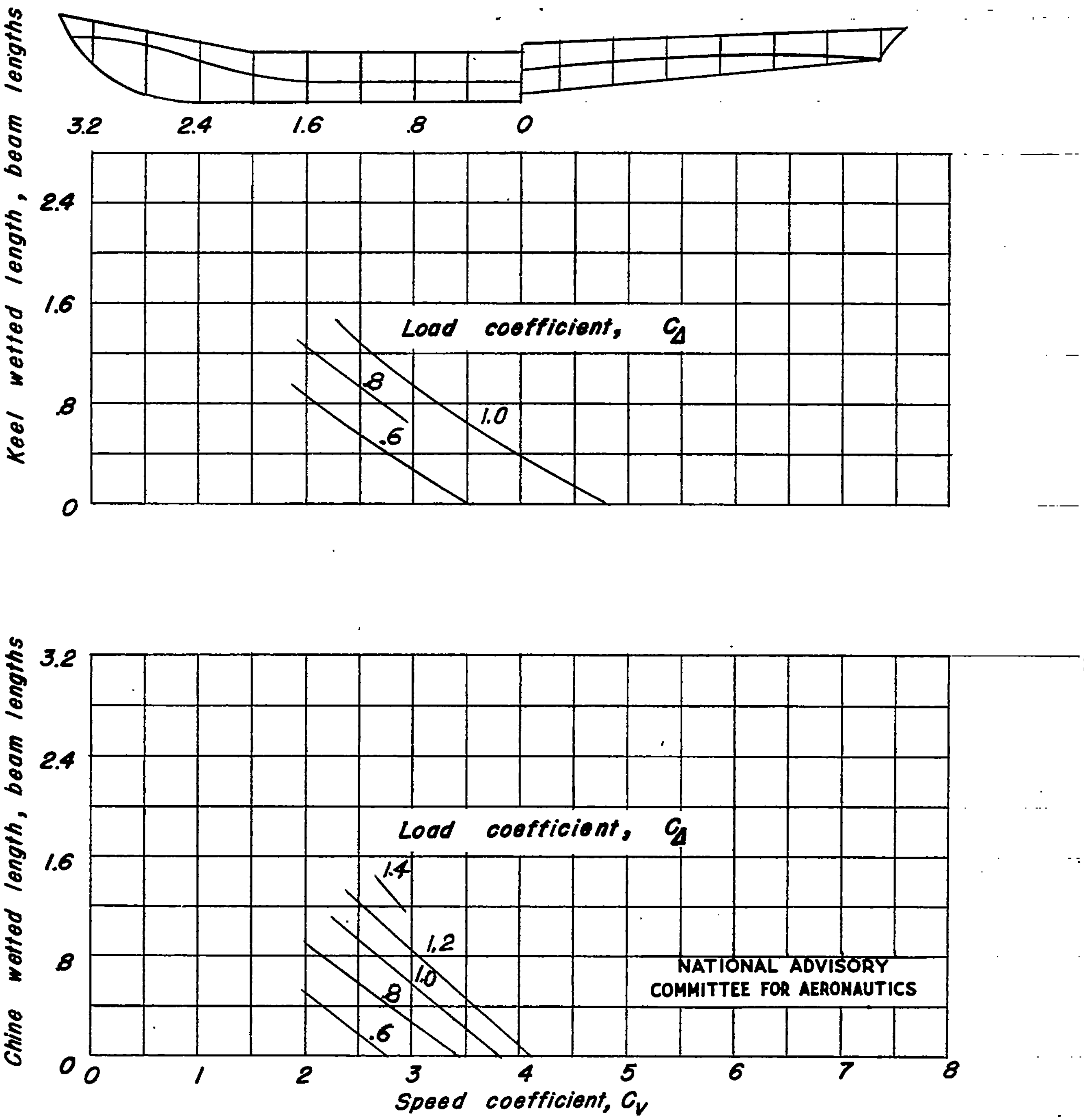
(f) Trim, 11°.

Figure 8.– Continued.



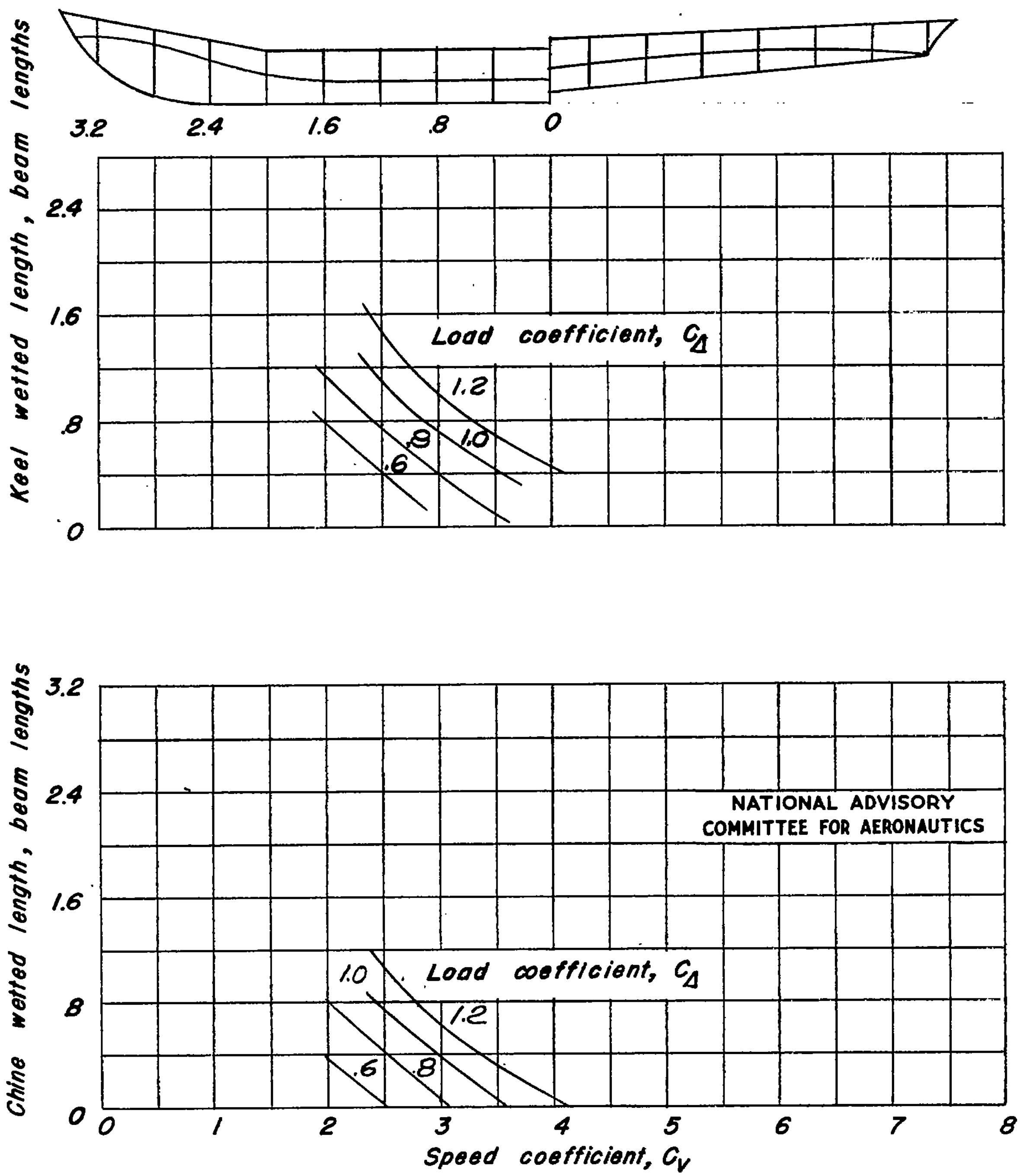
(g) Trim, 12°.

Figure 8.– Continued.



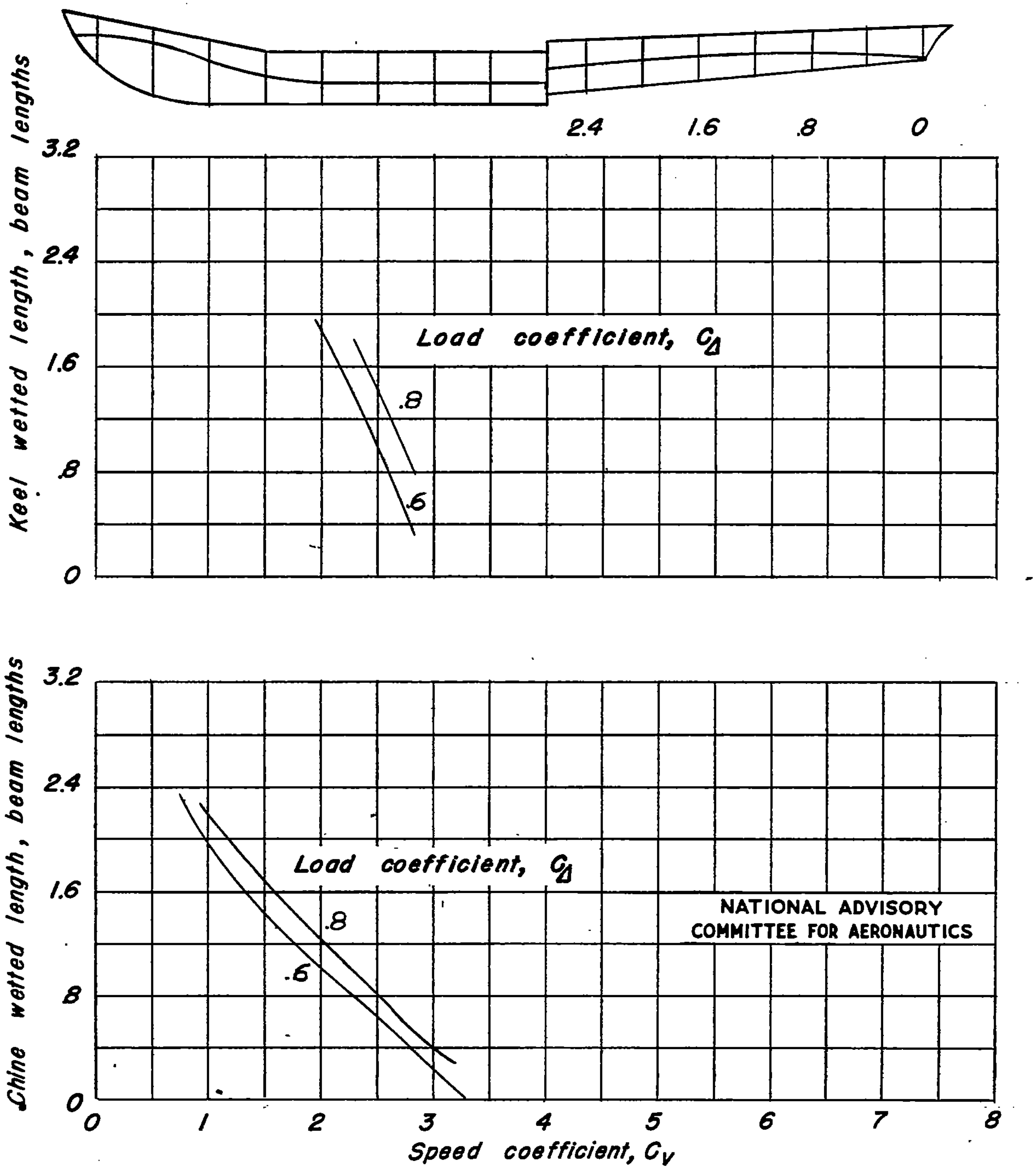
(h) Trim, 13°.

Figure 8.– Continued.



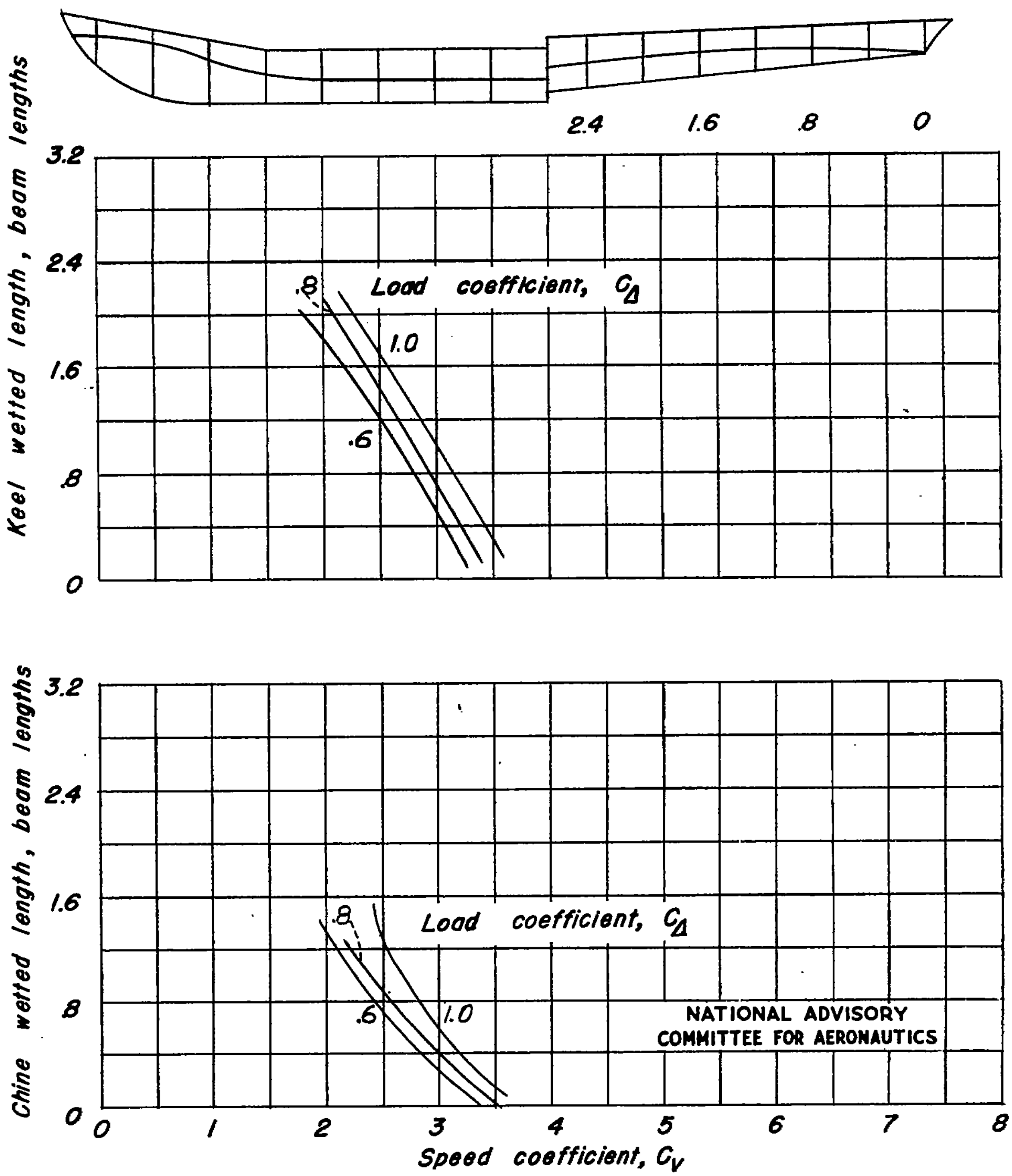
(i) Trim, 14°.

Figure 8.– Concluded.



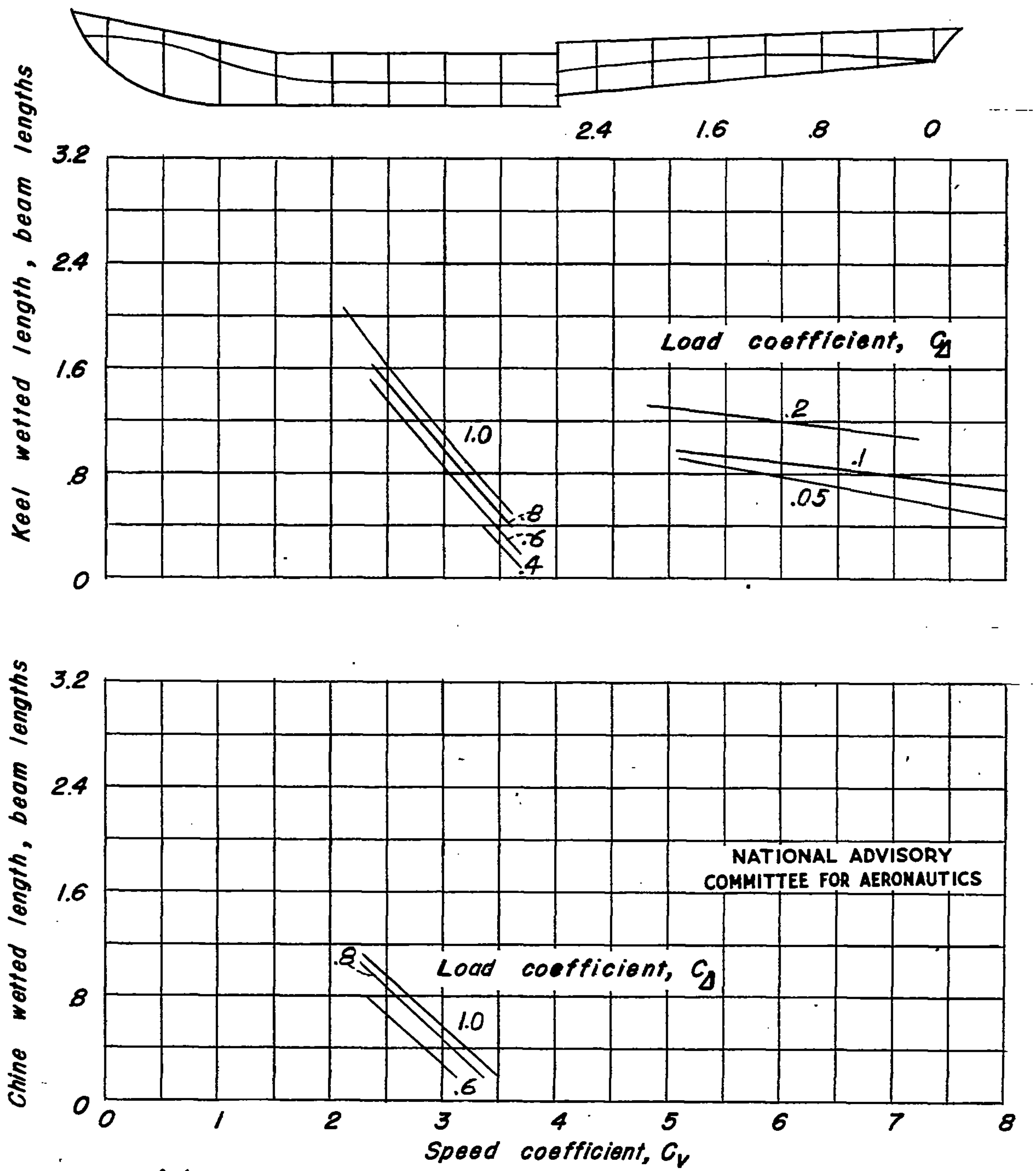
(a) Trim, 4°.

Figure 9.– Afterbody keel and chine wetted lengths. Model 175 FA.



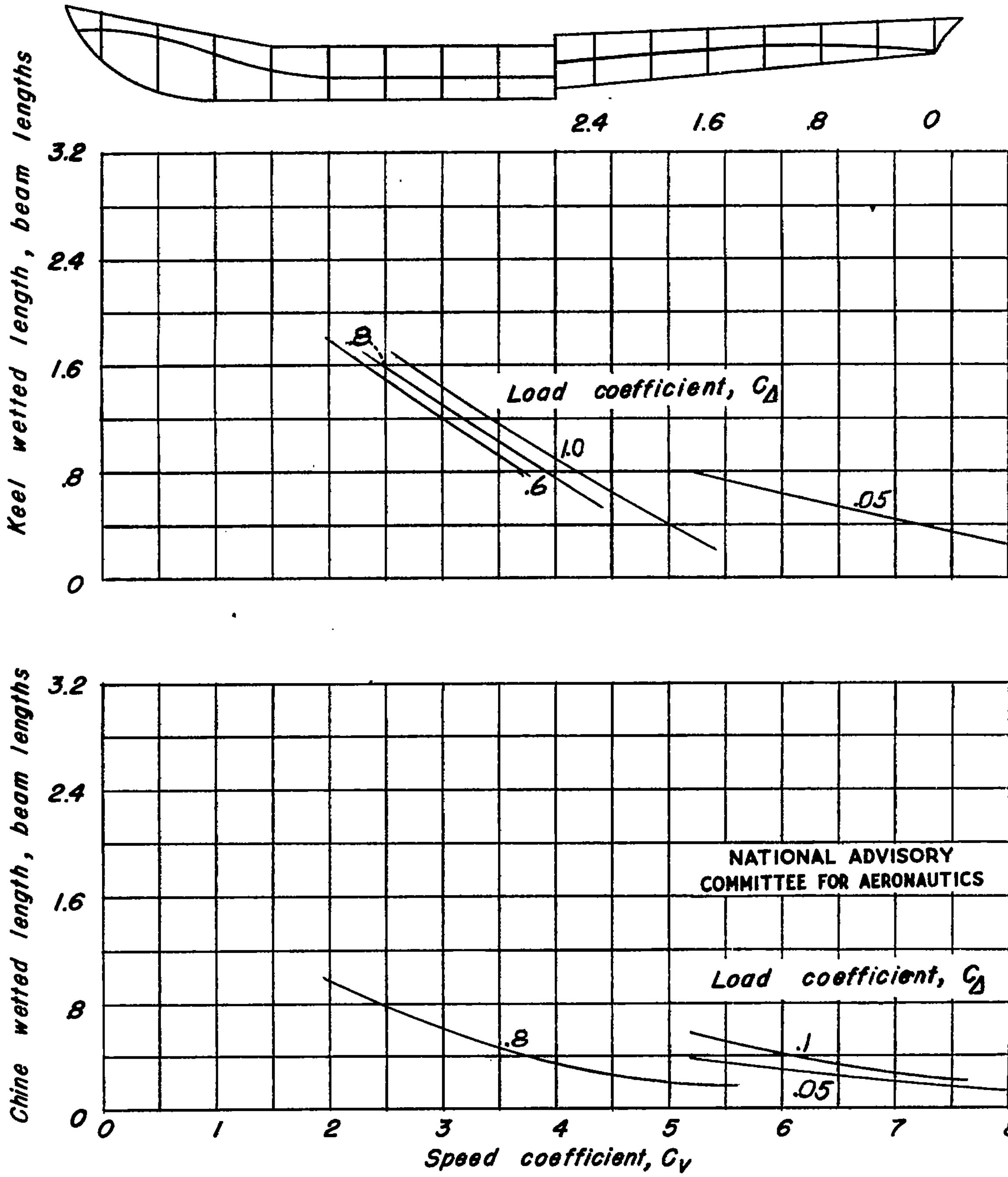
(b) Trim, 6°.

Figure 9.– Continued.



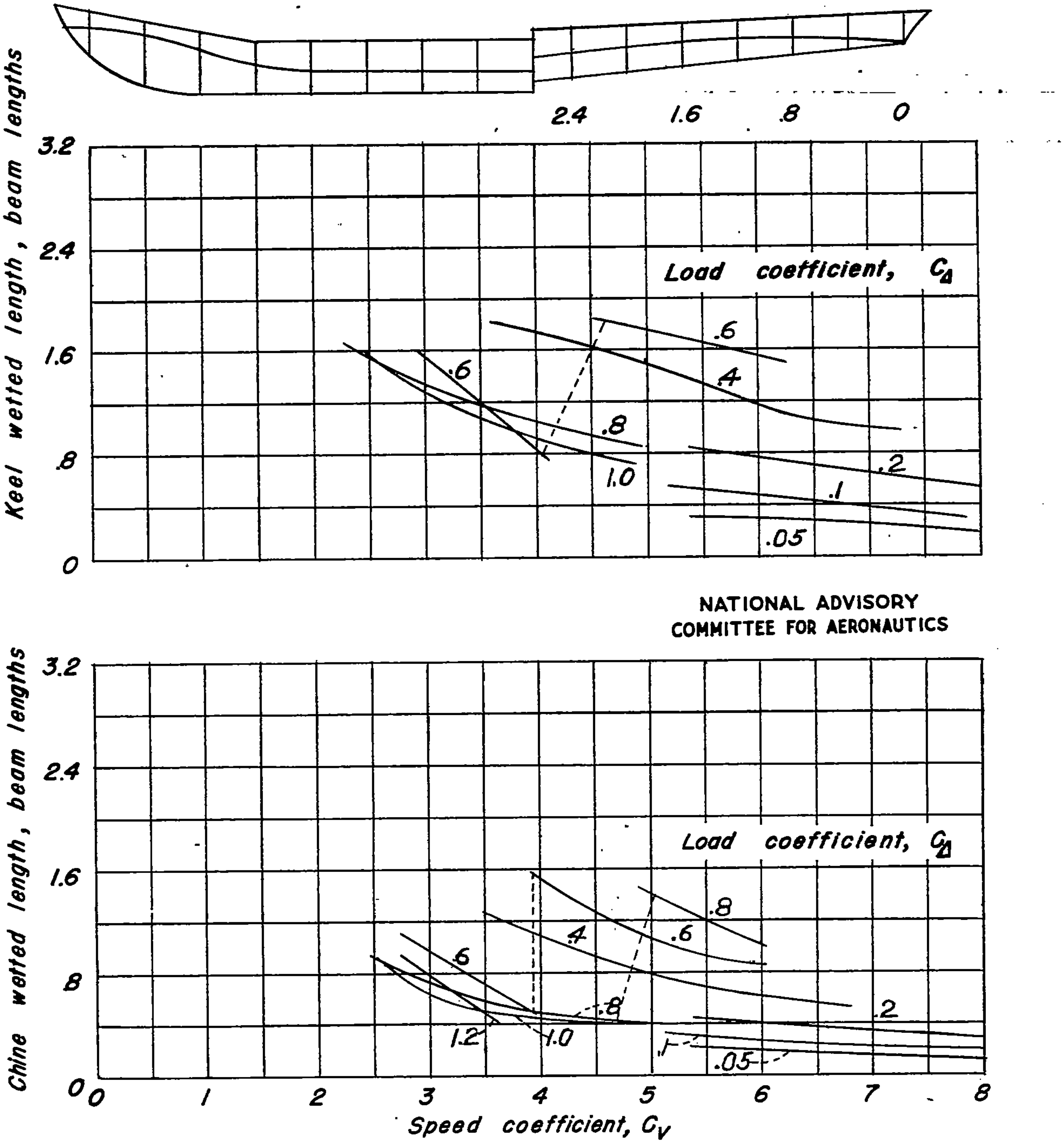
(c) Trim, 8°.

Figure 9.– Continued.



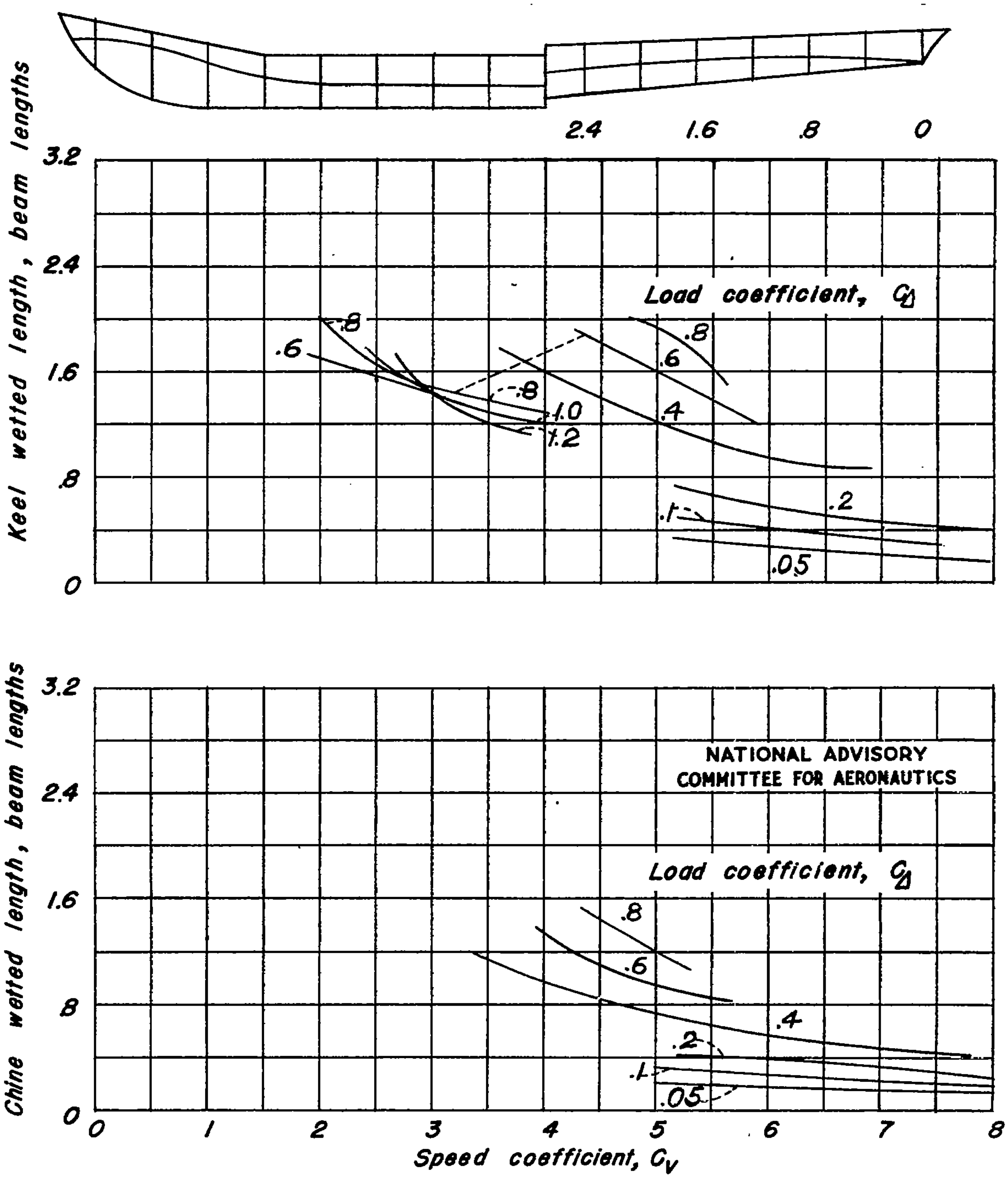
(d) Trim, 10°.

Figure 9.– Continued.



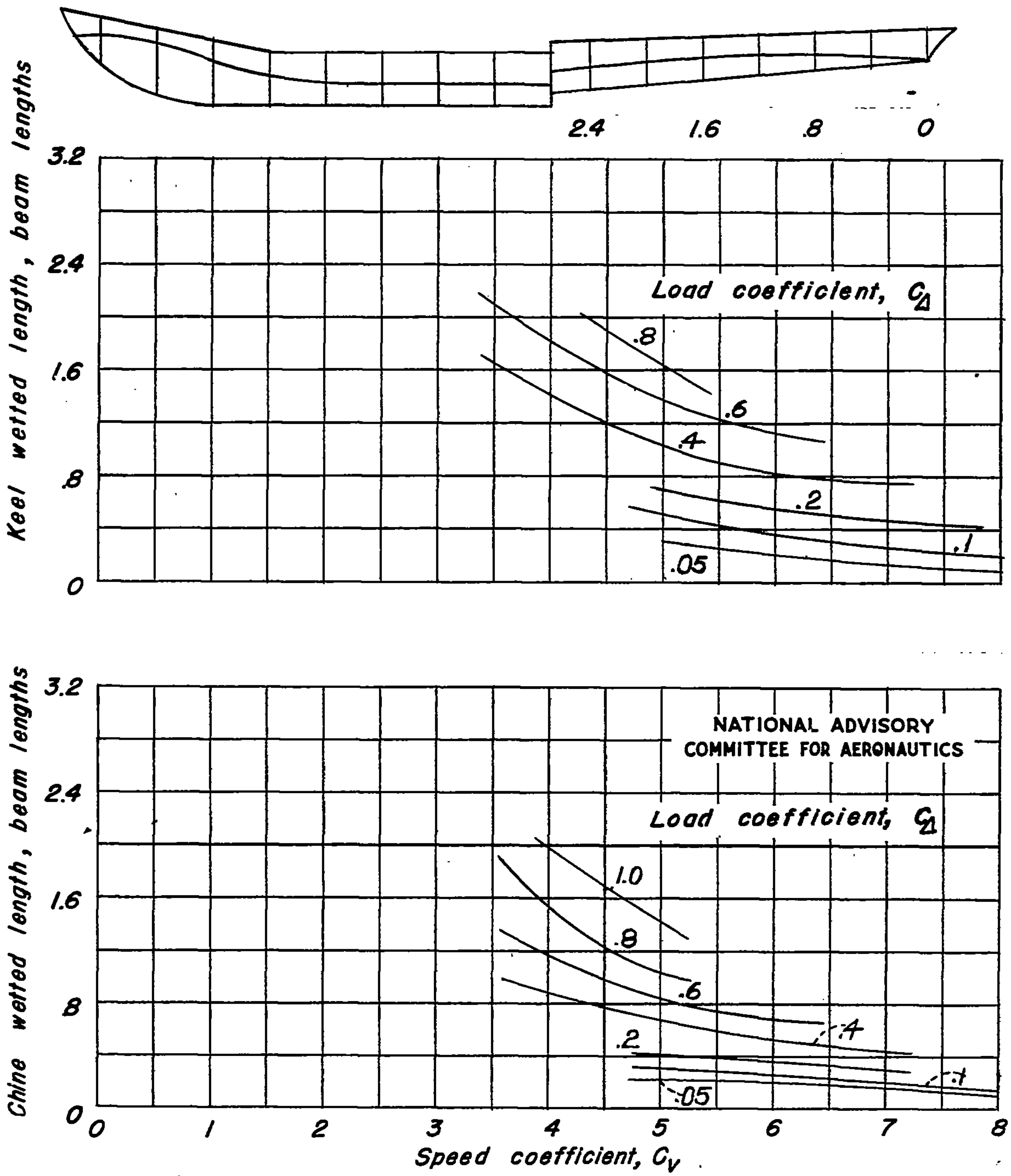
(e) Trim, 11°.

Figure 9.– Continued.



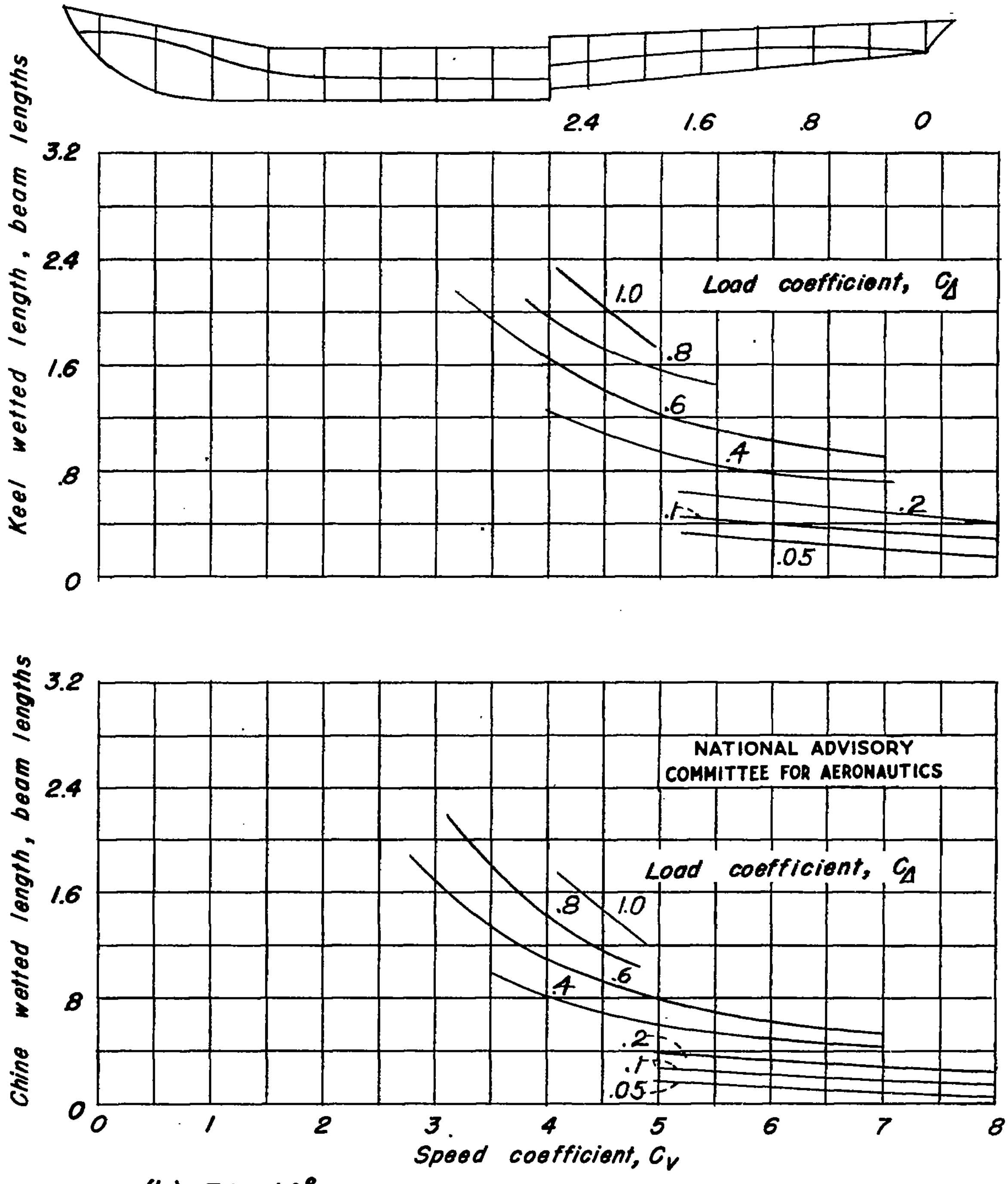
(f) Trim, 12°.

Figure 9.– Continued.

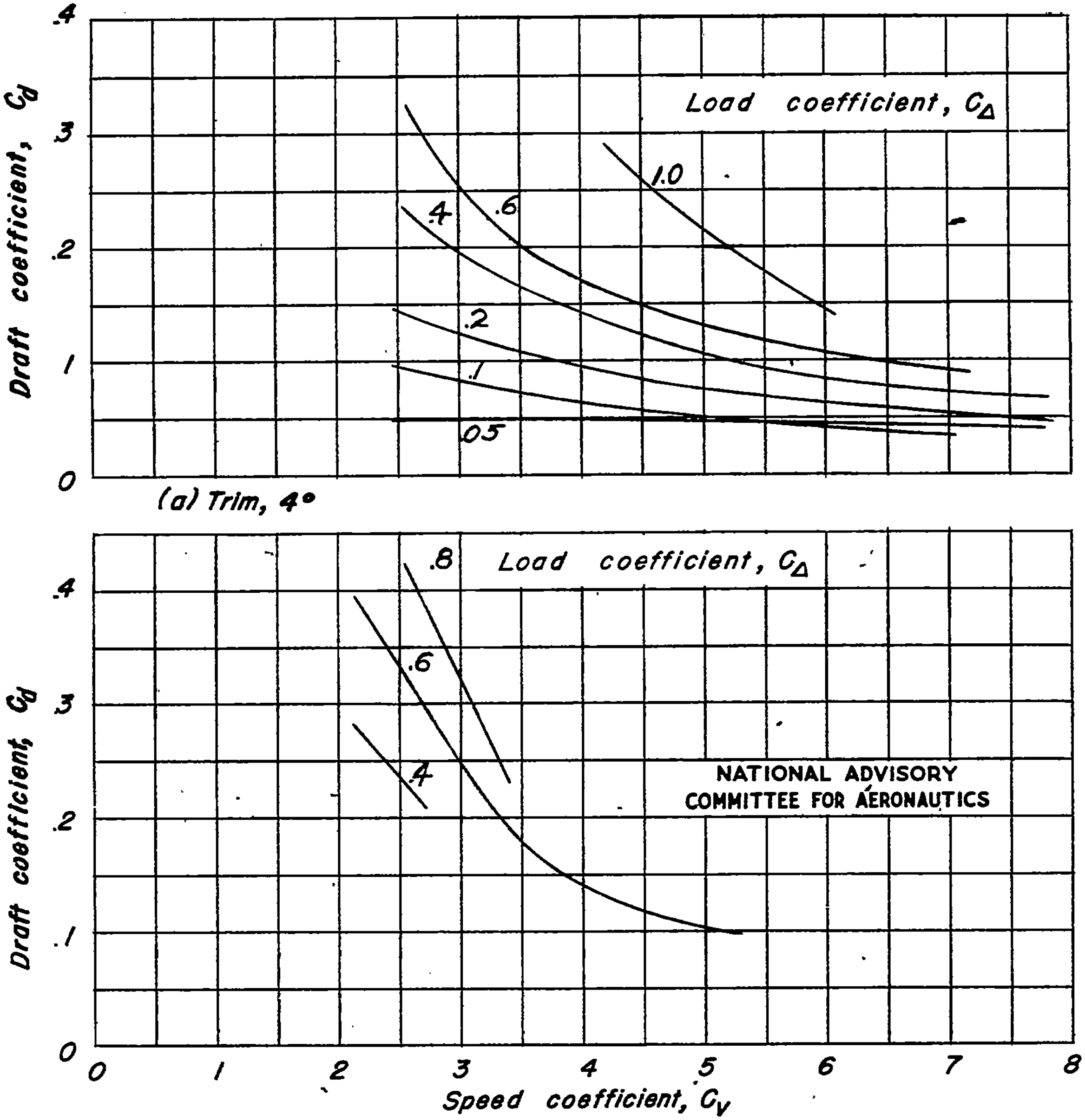


(g) Trim, 13°.

Figure 9.- Continued.

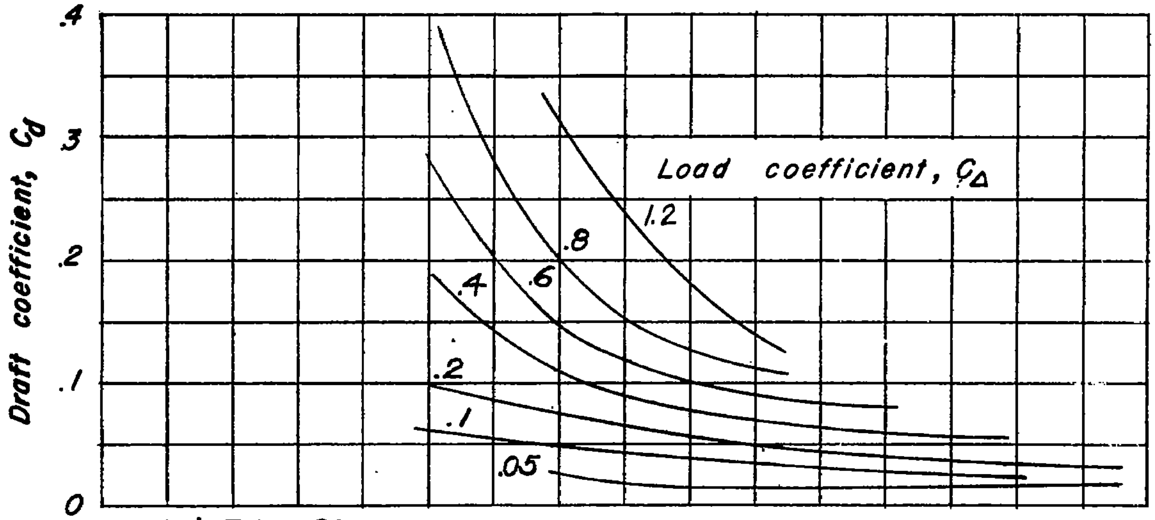


(h) Trim, 14°.
Figure 9.– Concluded.

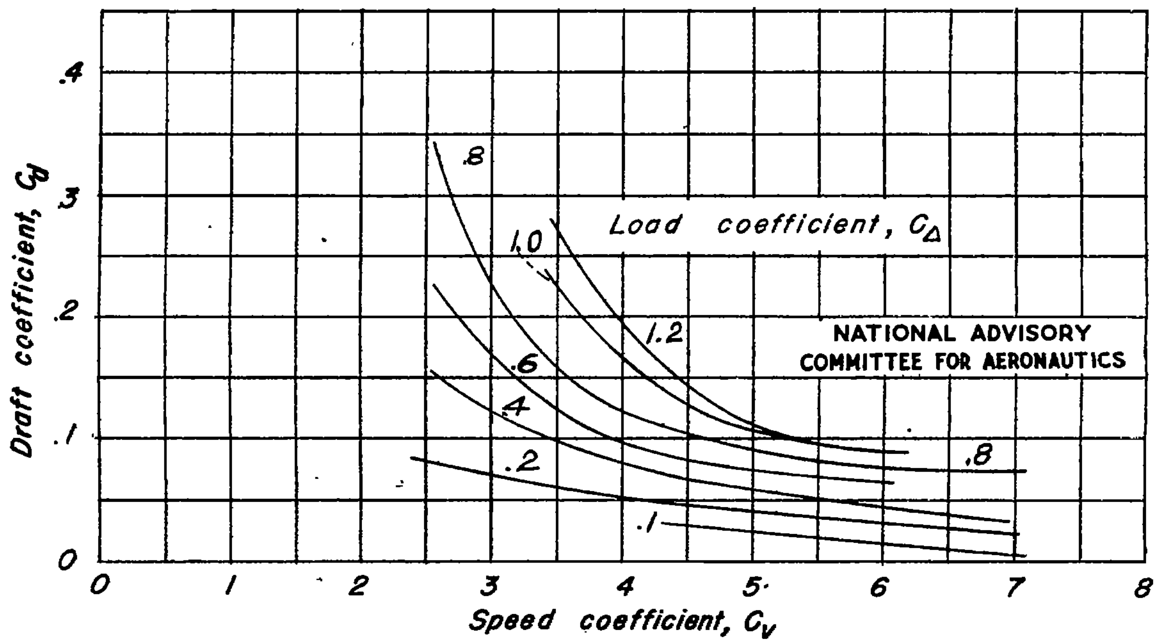


(b) Trim, 6°.

Figure 10.- Draft. Model 175F.



(c) Trim, 8°



(d) Trim, 10°.

Figure 10.-Concluded.